Silurian Linguliformean Brachiopods and Conodonts from the Cobra Formation, Southeastern New South Wales, Australia

James L. Valentine, Damian J. Cole and Andrew J. Simpson

Centre for Ecostratigraphy and Palaeobiology, Department of Earth and Planetary Sciences, Macquarie University, NSW 2109, Australia

Valentine, J.L., Cole, D.J. and Simpson, A.J. (2006). Silurian linguliformean brachiopods and conodonts from the Cobra Formation, southeastern New South Wales, Australia. *Proceedings of the Linnean Society of New South Wales* **127**, 199-234.

Silurian linguliformean brachiopods and conodonts are documented and described from the type section through the Cobra Formation (Taralga Group) in Murruin Creek, near Taralga. The linguliformean brachiopod fauna includes linguloids (six taxa), discinoids (three taxa), acrotretoids (four taxa) and a siphonotretoid. These are the first Late Silurian linguliformean brachiopods to be documented from eastern Australia. New taxa include *Acrotretella dizeugosa* sp. nov., upon which is based the first detailed description of the ontogeny of *Acrotretella* Ireland, 1961. Eleven multi-element conodont taxa are recognised, including the temporally significant taxon, *Kockelella maenniki* Serpagli and Corradini, 1998. Based on these conodont data, and other faunal elements, the Cobra Formation in Murruin Creek appears to range from mid-Wenlock? to mid-Ludlow (early to mid-*siluricus* Zone) in age.

Manuscript received 23 June 2005, accepted for publication 7 December 2005.

KEYWORDS: Brachiopods, Cobra Formation, Conodonts, Linguliformea, Ludlow, New South Wales, Silurian.

INTRODUCTION

The Cobra Formation (Taralga Group) crops out in a thin, north-south trending belt east of Taralga in southeastern New South Wales (Fig. 1). Despite extensive studies of a number of sections through the Cobra Formation (eg. Jongsma 1968; Roots 1969; Scheibner 1973; Morritt 1979; Powell and Fergusson 1979a; Pickett 1982; Matthews 1985), no detailed accounts or systematic descriptions of the numerous fossil groups from these sections have been published. The present investigation focuses on linguliformean brachiopods and conodonts recovered from the Cobra Formation in Murruin Creek, approximately 20 km north of Wombeyan Caves (Fig. 2).

The only report of linguliformean brachiopods from the Taralga Group is restricted to a single occurrence of *Schizotreta* sp. from the base of the Cobra Formation in Murruin Creek (Sherwin 1970). Silurian linguliformean brachiopods from eastern Australia are generally poorly known, with the only well-documented fauna being from the Early Silurian (Llandovery-Wenlock) Boree Creek Formation of central-western New South Wales (Dean-Jones 1979; Valentine and Brock 2003; Valentine et al. 2003). These are the first Late Silurian linguliformean brachiopods to be documented and described from eastern Australia.

Previous accounts of conodonts from the Taralga Group are restricted to the Wombeyan Limestone (Sherwin 1969; revised by Pickett 1982), a biohermal unit interpreted as Late Silurian in age, and stratigraphically equivalent to the base of the Cobra Formation in Murruin Creek (Naylor 1937; Jongsma 1968; Scheibner 1973). Based on a single Pa element assigned to '*Spathognathodus*' (= *Pandorinella*) *exigua* (Philip, 1966), Sherwin (1969) suggested that the Wombeyan Limestone was Early Devonian in age. However, in his biostratigraphic review of Australian Silurian conodonts, Simpson (1995a:339) stated that this element could be a morphotype of *Ozarkodina confluens* (Branson and Mehl, 1933), a late Silurian species. No conodonts have previously been reported from the Cobra Formation.

GEOLOGY AND STRATIGRAPHY

The Early Silurian (mid-Wenlock?) to Early Devonian Taralga Group, cropping out east of Taralga, is an upward-shallowing, deepwater sequence deposited along the eastern limb of the Cookbundoon Synclinorium, on the western edge of the Capertee High in the Hill End Trough (Scheibner 1973; Powell and Fergusson 1979b; Matthews 1985) (Fig. 1). The Cobra Formation forms the basal unit of the Taralga Group and consists of ~670 m of interbedded fine-grained micrites, siltstones and limestones (Pickett 1982; Matthews 1985). Based on the fine detrital nature of the Cobra Formation, the orientation of fossil corals, and the occurrence of the calcareous alga, *Pseudochaetetes* Haug, 1883 in association with the tabulate coral, *Entelophyllum* sp., from the base of the Cobra Formation in Little Wombeyan Creek (Fig. 1), Pickett (1985) concluded that the Cobra Formation was of turbiditic origin. Disarticulated rhynchonelliformean brachiopods from the same horizons are all deposited concave side down, suggesting post-mortem transportation via traction currents (Matthews 1985).

The Cobra Formation overlies the low grade metamorphic shales and greywackes of the Late Ordovician to Early Silurian Burra Burra Creek Formation (uppermost unit of the Triangle Group) (Figs 1, 2). The contact between the two units is widely stated to faulted, or a high angle unconformity, and a significant time break has been implied to exist between them (Jongsma 1968; Roots 1969; Scheibner 1973; Talent et al. 1975; Powell et al. 1976; Powell and Fergusson 1979a, b; Pickett 1982). In contrast, both Morritt (1979) and Matthews (1985) have argued that this contact is paraconformable (though sometimes faulted) as in Murruin, Kerrawary, Guineacor and Cowhorn creeks, or gradational over about 15 m as in Little Wombeyan Creek (Fig. 1).

No evidence of a high angle unconformity between the Burra Burra Creek and Cobra formations was observed in Murruin Creek. The contact is marked by a prominent, 14 m thick conglomeritic horizon, whose upper boundary marks the start of the MU section (Figs 2, 3). Matthews (1985) argued that this conglomeritic horizon only occurs where faulting (parallel and/or subparallel to bedding) exists between the Burra Burra Creek and Cobra formations. The fault, and associated conglomerate, can occur within either formation, or as in Murruin Creek, at the contact between the two. Where faulting is absent, as in Little Wombeyan Creek, the conglomeritic horizon is also absent. Therefore, this horizon would appear to have originated through post-lithification tectonic activity (Matthews 1985).

The first 468 m of the MU section through the Cobra Formation consists of well-bedded, grey-black shales (4-25 cm thick) interbedded with pale coloured, nodular limestone bands (1-6 cm thick) and dark-grey limestone beds (up to 1.8 m thick) (Fig. 3). However, continuously exposed horizons are restricted to 126-171 m and 431-468 m above the base of the MU section (Fig. 3). Between these intervals, only sporadic outcrops of grey-black shales and nodular limestones, identical to those occurring in the interval 126-171 m above the base of the MU section, were observed.

The only linguliformean brachiopod recovered from this part of the MU section was a single dorsal valve of *Orbiculoidea* sp. from sample MU 21 (174.6 m above the base of the section) (Table 1). Conodonts from this part of the MU section are all predominantly long ranging forms and include *Panderodus unicostatus* (Branson and Mehl, 1933), *Panderodus recurvatus* (Rhodes, 1953) and *Dapsilodus obliquicostatus* (Branson and Mehl, 1933) (Table 2). This fauna is broadly suggestive of a Wenlock to Pridoli age.

Jongsma (1968), Roots (1969) and Scheibner (1973) all recorded *Batocara mitchelli* (Foerste, 1888) within the first 175 m of their respective sections through the Cobra Formation in Murruin Creek. This species ranges from the mid-Wenlock to mid-Ludlow in Australia (Pickett et al. 2000). Corals identified by Sherwin (1969) and Pickett (1985) from the base of the Cobra Formation in Little Wombeyan Creek (Fig. 1) belong to the Hatton's Corner coral assemblage (Strusz and Munson 1997; Munson et al. 2000) and suggests a late Wenlock to Ludlow age. Therefore, the base of the Cobra Formation would appear to be, at most, mid-Wenlock in age.

Continuously cropping out horizons occur for the last 64.2 m of the MU section, beginning 605 m above its base (Fig. 3). This part of the MU section consists of well-bedded, dark-grey limestone horizons (up to 20 cm thick) interbedded with thicker intervals of soft, light brown mudstones between 605-623.1 m above the base of the MU section. Several faults also occur in this part of the Cobra Formation (Fig. 2)—one at 623.1 m above the base of the MU section, where massive black limestones replace the mudstone horizons. These limestone horizons continue through to the top of the Cobra Formation (Fig. 3). This part of the MU section has undergone folding as part of the latest Devonian to early Carboniferous regional deformation event that affected the Hill End Trough (Powell et al. 1976).

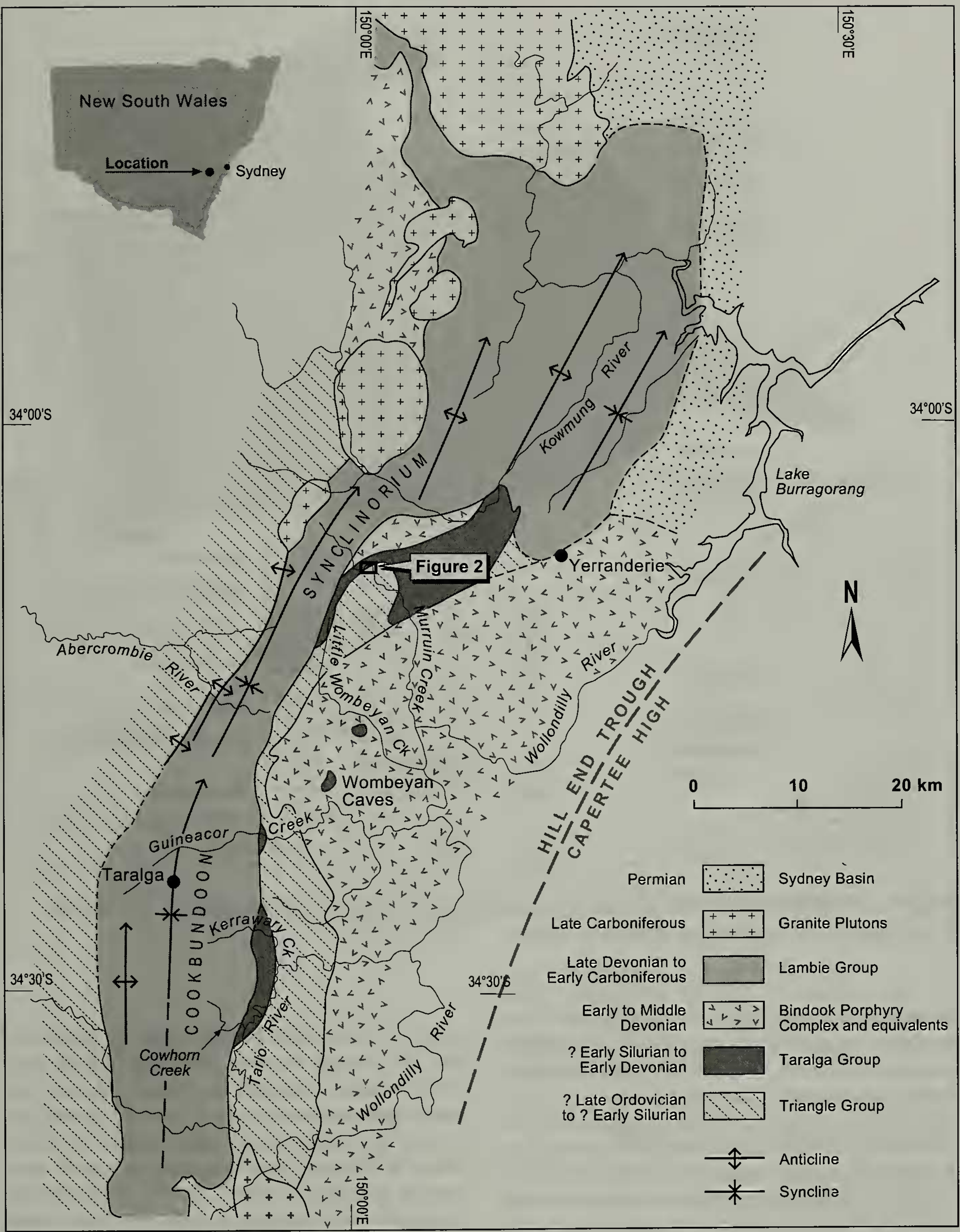


Figure 1. Generalised regional geological map of the Taralga area showing where the Taralga Group crops out (modified after Powell and Fergusson 1979a). Study area in Murruin Creek is indicated by boxed area and enlarged in Fig. 2.

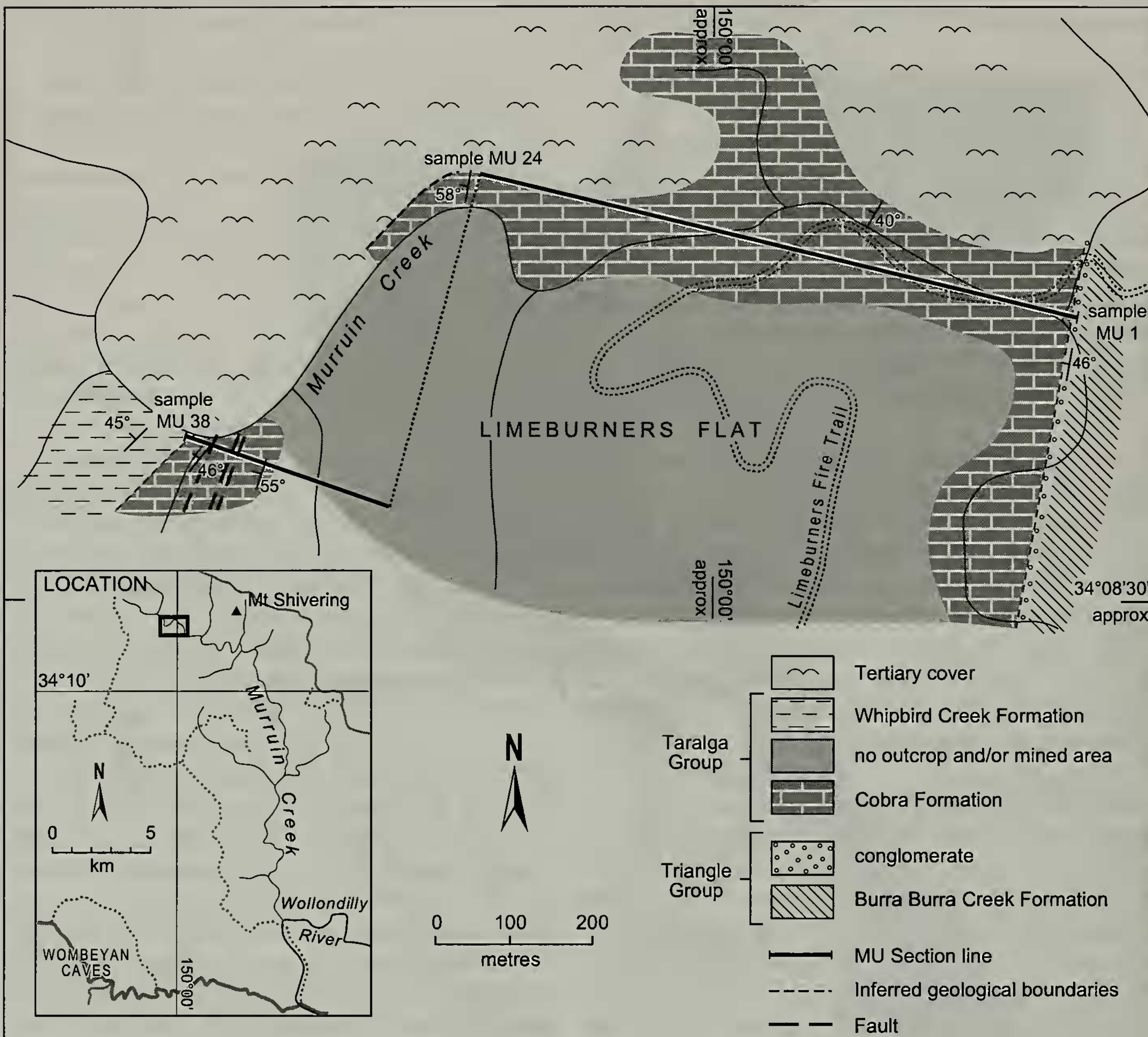
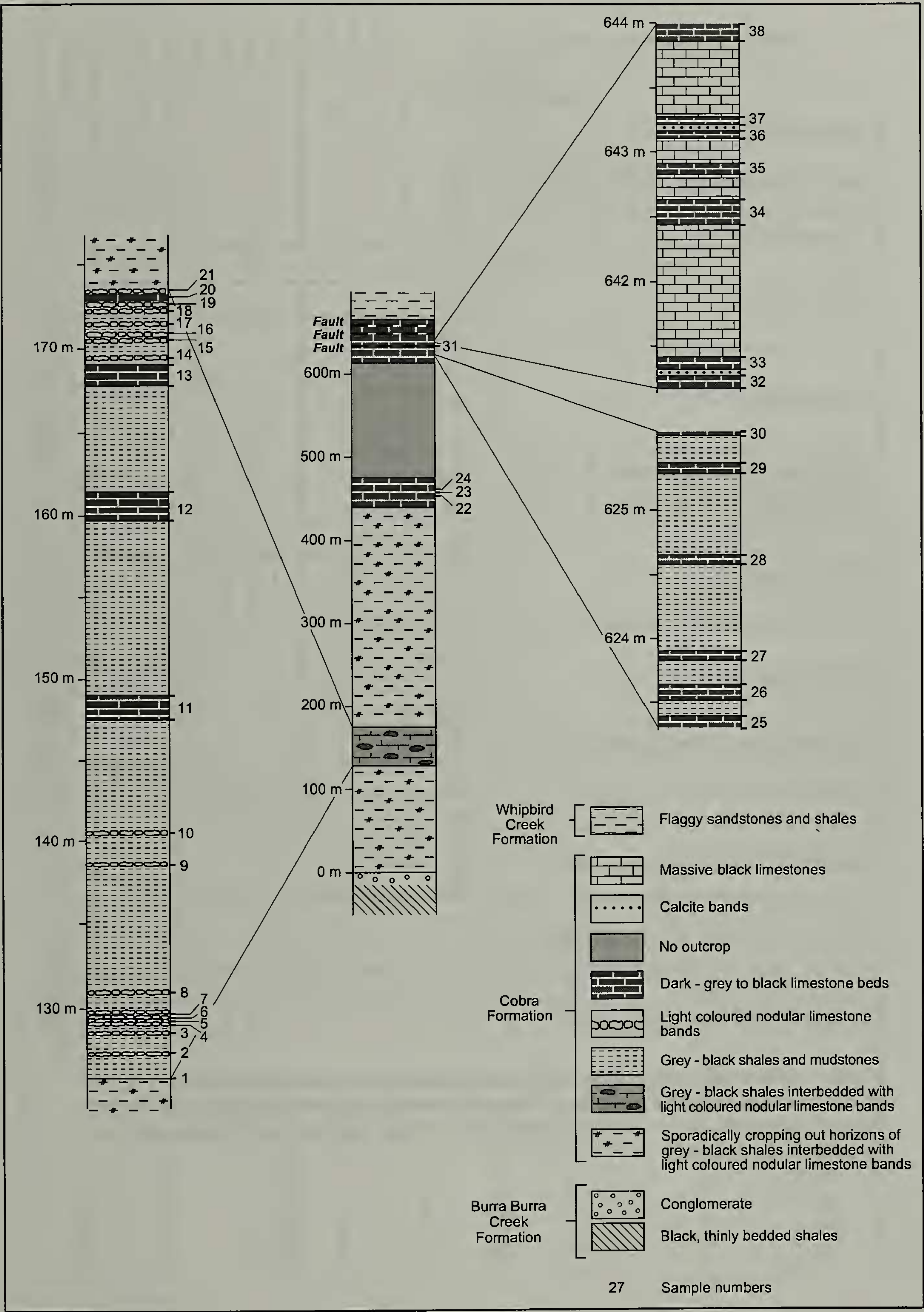


Figure 2. Detailed geological map of study area in Murruin Creek, showing location of MU section. Note that the MU section runs from right to left.

The change in lithology to massive black limestones coincides with a dramatic increase in the number of linguliformean brachiopods and conodont elements recovered. The linguliformean brachiopod fauna is dominated by acrotretoids, particularly *Opsiconidion ephemerus* (Mergl, 1982) (Table 1). This species ranges from the upper Ludlow of the Kopanina Formation to the Pridoli Požáry Formation of the Czech Republic and broadly agrees with the Ludlow age determination for the upper part of the MU section based on conodont data (see below). In fact, the Murruin Creek linguliformean brachiopod assemblage is similar to that described by Mergl (2001) from the deepwater Ludlow Kopanina Formation in the Barrandian of the Czech Republic. The Kopanina fauna, also dominated by acrotretoids,

Figure 3. (OPPOSITE) Stratigraphic column of the MU section showing lithology and all sampled horizons. Numbers on the left of each column represent metres above the base of the MU section and those on the right, sample numbers. Detail of lithology and sampling for the 47 m of section from sample MU 1 to MU 21 is enlarged to the left. Note that due to scale, only those nodular limestone horizons sampled in this interval are included. Detail of lithology and sampling for the 2.51 m of section from sample MU 25 to MU 30, and for the 0.9 m of section from sample MU 32 to MU 38, are enlarged to the right.


644 m
643 m
642 m
625 m
624 m
170 m
160 m
150 m
140 m
130 m
600m
500 m
400 m
300 m
200 m
100 m
0 m
Fault
Fault
Fault
Whipbird Creek Formation
Flaggy sandstones and shales
Cobra Formation
Massive black limestones
Calcite bands
No outcrop
Dark - grey to black limestone beds
Light coloured nodular limestone bands
Grey - black shales and mudstones
Grey - black shales interbedded with light coloured nodular limestone bands
Sporadically cropping out horizons of grey - black shales interbedded with light coloured nodular limestone bands
Burra Burra Creek Formation
Conglomerate
Black, thinly bedded shales
27 Sample numbers

Metres above base of MU section		174.6	628.6	641.3	642.6	642.9	643.1	Totals
Brachiopod Taxa	Sample Numbers	21	31	32	34	35	36	
pseudolingulid gen. et sp. indet. 1	vv					1	1	2
	dv			1		2	2	5
Kosagittella? sp.	vv			1		1		2
Rowellella? sp.	vv?						1	1
	dv?						2	2
	frag					1	19	20
Paterula sp.	vv						1	1
	dv						2	2
	co					1		1
linguloid gen. et sp. indet. 1	frag						8	8
linguloid gen. et sp. indet. 2	dv					1		1
Orbiculoidea sp.	vv				2			2
	dv	1	2	1	2	2	6	14
	frag		22	1	6	4	7	40
Schizotreta sp.	vv		2				1	3
	dv		3	4		3	6	16
	frag		4	2		12	21	39
discinoid gen. et sp. indet. 1	dv					1	1	2
Artiotreta sp. cf. *A. longisepta*	dv		29	9	1	5	19	63
	co		1	1			1	3
Acrotretella dizeugosa sp. nov.	vv		25	6		3	2	36
	dv		23	7		5	4	39
Opsiconidion sp. cf. *O. ephemerus*	vv		4	8		8	14	34
	dv		19	24		16	20	79
Opsiconidion sp.	dv		8	2		3	3	16
siphonotretid gen. et sp. indet. 1	dv				2		1	3

Table 1. Distribution and abundance of each linguliformean brachiopod species recovered from productive samples along the MU section through the Cobra Formation in Murruin Creek. Abbreviations: vv = ventral valve(s); dv = dorsal valve(s); frag = fragment(s); co = conjoined specimen(s).

Metres above base of MU section		127.6	129.1	130.4	131.5	133.3	140.3	142.3	149.9	161.9	169.9	174.4	174.6	623.4	623.6	628.6	641.3	641.4	642.6	642.9	643.1	643.3	644.0	Totals
Conodont Taxa	Sample Numbers	1	2	3	6	8	9	10	11	12	13	20	21	25	26	31	32	33	34	35	36	37	38	
Belodella anomalis	Sa																				2			2
	Sb																		6				1	7
	Sc																		2			1		3
	Sd																		2					2
	M																		6		1		1	8
	T																		1					1
Dapsilodus obliquicostatus	S																		10			7	15	32
	M											3			2				49		18	30	57	159
Decoriconus fragilis	Sc											2							1		3	3		9
Panderodus recurvatus	Sa														3				4			1		8
	Sb														4				20		8	2		34
	Sc																		1					1
	M														1									1
Panderodus serratus	Sb																		2					2
	Sc																		2					2
	M																				2			2
Panderodus unicostatus	Sa		2	2	1		1				1	6	2		5				214		65	60	59	418
	Sb					1	2		1			4			2	1			123		17	45	121	317
	Sc		1					1							3				117		39	63	119	343
	M				1	1				2		2			1			1	92		76	43	40	259
Coryssognathus dubius	Pa																		1					1
	Sb																		3					3
Oulodus sp. cf. *Oulodus elegans*	Sa																		1					1
	Sb																		1					1
Ozarkodina excavata excavata	M																		2				1	3
	Pa															1			16		3	10	6	36
	Pb	1												2			2		18		3	9	5	40
	Sa																		8		1	9	3	21
	Sb											2				2			13	2	7	19	10	55
	Sc																		8		4	15	11	38
Kockelella maenniki	Pa																		1					1
	Sc																		1					1
Unassigned elements													2		2		1		11		9			25

Table 2. Distribution and abundance of each conodont species recovered from productive samples along the MU section through the Cobra Formation in Murruin Creek.

Abbreviation	Explanation
L	valve length
W	valve width
H	valve height
WI	width of pseudointerarea
LI	maximum length of pseudointerarea
Fa	length of pedicle foramen
Fw	width of pedicle foramen
Fp	point of origin of pedicle foramen
LS	length of dorsal valve median septum
BS	point of origin of dorsal valve median septum
MHS	maximum height of dorsal valve median septum
OSP	point of origin of surmounting plate
LSP	length of surmounting plate
WSP	width of surmounting plate
LP	length of larval shell
WP	width of larval shell
HP	height of larval shell
N	number of measurements
MEAN	average value
SD	standard deviation
MAX	maximum value
MIN	minimum value

Table 3. Abbreviations used for measurements (in μm) of linguli formean brachiopods. Abbreviations based on those of Popov and Holmer (1994:35, fig. 39). Where applicable, all measurements are made from the posterior margin.

includes numerous small discinids and rarer occurrences of larger discinids, obolids, linguloids and a siphonotretoid (Mergl 2001).

The majority of the conodonts recovered from this part of the MU section were the same long ranging forms occurring in the lower part of the MU section (Table 2). The lenticular and triangular elements of *Belodella anomalis* Cooper, 1974 recovered from Murruin Creek (Table 2) are all broad-based (Fig. 4a-g). Simpson (1995b: 310) and Jeppsson (1989) noted a general morphological trend in this taxon of broad-based elements in the Ludlow (eg. Cooper 1974:pl. 1, figs 1-10; Simpson et al. 1993:fig. 4G-I; Simpson 1995b:pl. 16, fig. 15) and narrower-based elements in the Pridoli (eg. Jeppsson 1989: pl. 1, fig. 15; Simpson 1995b:pl. 16, fig. 21). Farrell (2004), however, documented a relatively broad-based population of elements from the Camelford Limestone and interpreted this sequence as Pridoli in age. Sample MU 34 (642.6 m above the base of the section) also yielded a single Pa and M element of the temporally significant taxon, *Kockelella maenniki* Serpagli and Corradini, 1998 (Table 2). This species is restricted to the early to mid-*siluricus* Zone (mid-Ludlow) of Europe and North America (Corradini and Serpagli 1999; Serpagli and Corradini 1999). In addition, a pygidium, possibly of *B. mitchelli*, was recovered from sample MU 28 (624.6 m above the base of the section) (Fig. 3). This is also in general agreement with the Ludlow age determination for this part of the MU section.

Conformably overlying the Cobra Formation in Cowhorn, Kerrawary, Guineacor and Little Wombeyan creeks (Fig. 1), are thinly bedded (<1 m thick), deep-water, turbiditic arenites, lutites and siltstones of the Argyle Formation (Scheibner 1973; Pickett 1982; Matthews 1985). In Murruin Creek, the Cobra Formation is conformably overlain by the Whipbird Creek Formation (Fig. 2), a turbiditic sequence of interbedded sandstones and shales that may represent a distal facies of the Argyle Formation. Matthews (1985) reported rare boundary faulting between the Cobra and Argyle formations in Little Wombeyan Creek and similar faulting occurs in the upper part of the Cobra Formation in Murruin Creek (Fig. 2). The contact between the Cobra and Whipbird Creek formations lies ~670 m above the base of the MU section (Fig. 3), compared to only 550 m reported by Scheibner (1973), Pickett (1982) and Matthews (1985). Given the folding and faulting occurring in this part of the Cobra Formation, the possibility of repeated horizons in the MU section cannot be dismissed.

SYSTEMATIC PALAEONTOLOGY

Discussion

All type, paratype and figured materials are lodged in the palaeontological collections of the Australian Museum, Sydney (AM F).

Phylum Brachiopoda Duméril, 1806

Measurements

Measurements (in μm) of linguliformean brachiopods are based on those of Popov and Holmer (1994:35, fig. 39). Abbreviations used for the measurement of all taxa are listed in Table 3. Note that the width of some incomplete specimens was determined by measuring half the width and multiplying by two, assuming a bilaterally symmetrical organism.

Order Lingulida Waagen, 1885
Superfamily Linguloidea Menke, 1828
Family Pseudolingulidae Holmer, 1991

pseudolingulid gen. et sp. indet. 1
Fig. 4a-f

Figured material

AM F328314 (Fig. 4a-c): ventral valve; AM F128315 (Fig. 4d): dorsal valve; AM F128316 (Fig. 4e, f): dorsal valve, sample MU 36. All from sample MU 35 unless otherwise mentioned (Table 1).

Discussion

The ventral valve pseudointerarea has a well-developed pedicle notch and small, subtriangular propareas (Fig. 4b, c). The posterior margin of the dorsal valve is thickened and has an undivided, anacline pseudointerarea (Fig. 4d). The larval shell is smooth and the post larval shell ornament consists of fine concentric filae (five per 10 μm) (Fig. 4a, e, f).

'*Lingula*' *lewisii* Sowerby, 1839, from the lower Ludlow Aymestry Limestone of Wales, was questionably referred to the pseudolingulids by Holmer (1991) based on similarities in vascular impressions and muscle scars with *Pseudolingula quadrata* (von Eichwald, 1829). '*Lingula*' *lewisii* differs by being more rectangular with sharper cardinal angles and is larger (average length 11.5 mm) (Cherns 1979; Bassett 1986). ?*Wadiglossa perlonga* (Barrande, 1879) from the Ludlow Kopanina Formation of the Czech Republic, is distinguished by its acutely pointed beak and post-larval shell ornament of low, poorly developed concentric growth lines (Mergl 2001).

Family Obolidae King, 1846
Subfamily Obolinae King, 1846
Kosagittella Mergl, 2001

Type species

Kosagittella clara Mergl, 2001.

Kosagittella? sp.
Fig. 4m-o

Figured material

AM F128321 (Fig. 4m-o): ventral valve, sample MU 32 (Table 1).

Discussion

The ventral valve has a thickened posterior wall and a weakly apsacline to orthocline pseudointerarea, medially divided by a parallel sided pedicle groove that continues forward of the pseudointerarea a short distance as a shallow groove (Fig. 4n). The subcircular larval shell is smooth and located marginally. The post-larval shell ornament consists of widely spaced concentric lamellae that are best developed on the lateral slopes (Fig. 4m). These characteristics recall *Kosagittella*, and in particular, *Kosagittella pinguis* Mergl, 2001 from the Lochkovian Lochkov Formation of the Czech Republic. However, the ventral valve pseudointerarea of the Murruin Creek specimens differ from *Kosagittella* in lacking laterally inclined propareas (Fig. 4o).

Family Zhantellidae Koneva, 1986
Rowellella Wright, 1963

Type species

Rowellella minuta Wright, 1963.

Rowellella? sp.
Fig. 4p-r

Figured material

AM F128322 (Fig. 4p): dorsal? valve; AM F128323 (Fig. 4q, r): ventral? valve. Both from sample MU 36 (Table 1).

Discussion

Although incomplete, these specimens appear to be elongately subrectangular to subtriangular in outline (Fig. 4p). The post-larval shell ornament consists of distinct concentric lamellae (six to seven per 100 μm) separated by flat interspaces bearing filae that are initially discontinuos laterally, but become concentric during later growth stages (Fig. 4q, r). The post-larval shell microornament of *Rowellella* cf. *R. lamellosa* Popov, 1976 (in Nazarov and Popov 1976) from Middle Ordovician strata in Sweden (Holmer 1989) consists of similar sets of discontinuous filae, but these are developed over the entire shell. *Rowellella distincta* Bednarczyk and Biernat, 1978 from the lower Arenig of the Holy Cross Mountains in Poland (Bednarczyk and Biernat 1978) and the Arenig Klabava Formation of the Czech Republic (Mergl 1995, 2002), also has a similar post-larval shell microornament, but has more prominent and widely spaced concentric lamellae. The post-larval shell microornament of *Rowellella* sp. from the Early Ordovician Bjørkåsholmen Limestone of Sweden and Norway (Popov and Holmer 1994) also consists of discontinuous sets of concentric filae, but these are only developed anteriorly.

The dorsal? valve interior of the Murruin Creek specimens has an elongate muscle field that

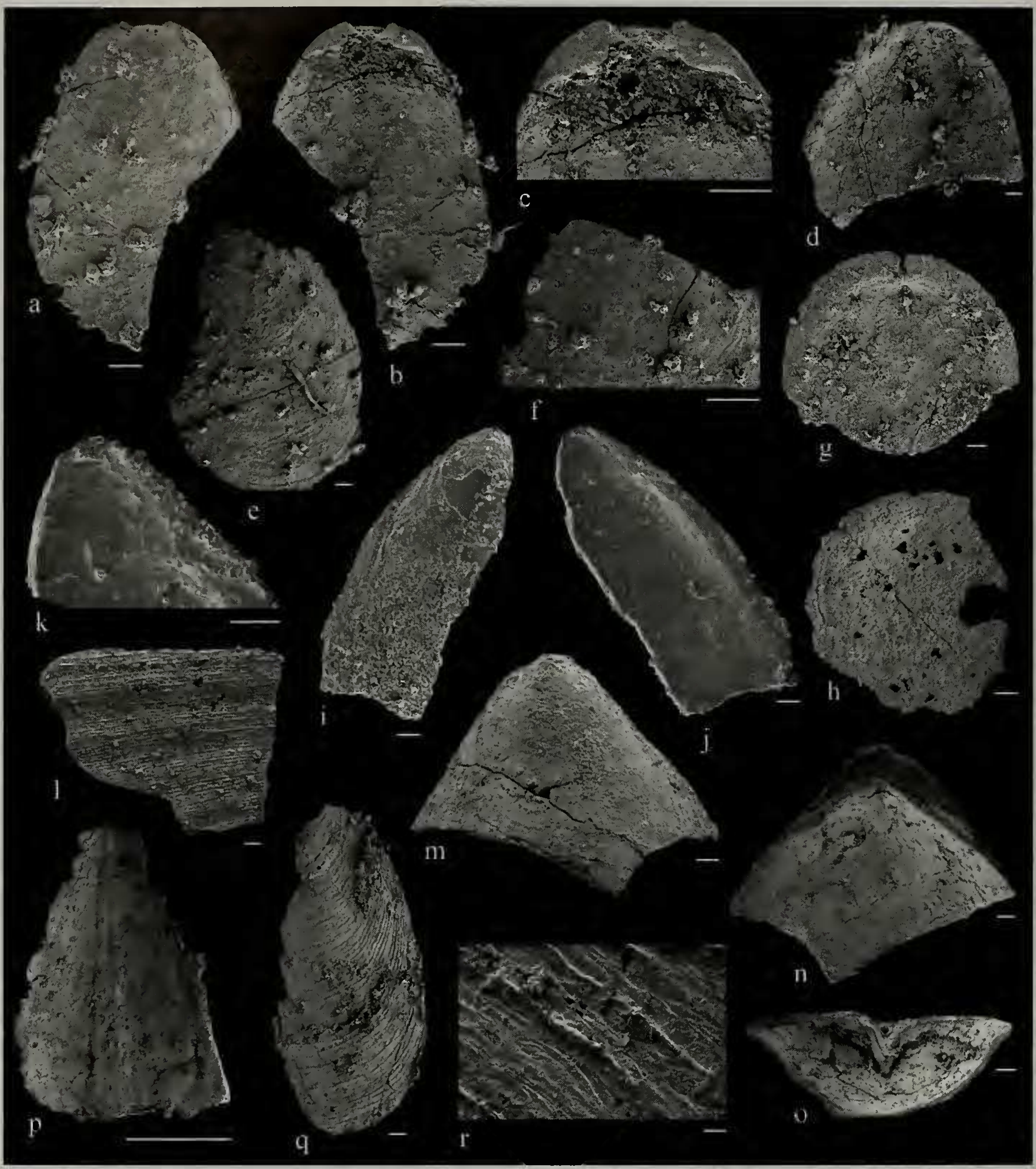


Figure 4. a-f. Pseudolingulid gen. et sp. indet. 1 all from sample MU 35 unless otherwise mentioned. a-c. Ventral valve AM F328314; a, exterior; b, interior; c, detail of pseudointerarea. d. Dorsal valve AM F128315, interior. e, f. Dorsal valve AM F128316, sample MU 36; e, exterior; f, detail of larval shell. g, h. *Paterula* sp. both from sample MU 36 g. Ventral valve AM F128317; interior. h. Dorsal valve AM F128318; exterior. i-k. Linguloid gen. et sp. indet. 2. Dorsal valve AM F128319, sample MU 35; i, exterior; j, interior; k, detail of pseudointerarea. l. Linguloid gen. et sp. indet. 1. Fragment of post-larval shell AM F128320, sample MU 36; exterior. m-o. *Kosagittella*? sp. Ventral valve AM F128321, sample MU 32; m, exterior; n, interior; o, anterior view. p-r. *Rowellella*? sp. both from sample MU 36 p. Dorsal? valve AM F128322; interior (scale bar equals 1000 μm). q, r. Ventral? valve AM F128323; q, exterior; r, detail of post-larval shell microornament (scale bar equals 10 μm). Unless otherwise mentioned all scale bars equal 100 μm.

expands slightly in width anteriorly, and is divided by a low, broad median ridge (Fig. 4p). This is similar to the dorsal valve interior of *Rowellella*? *parvicapera* Valentine, Brock and Molloy, 2003 from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales. The Murruin Creek specimens, however, lack the microornment of irregularly arranged wrinkles possessed by *R*? *parvicapera* on the interspaces between the concentric ridges on the post-larval shell (Valentine et al. 2003).

Family Paterulidae Cooper, 1956
Paterula Barrande, 1879

Type species
Paterula bohemica Barrande, 1879.

Paterula sp.
Fig. 4g, h

Figured material
AM F128317 (Fig. 4g): ventral valve; AM F128318 (Fig. 4h): dorsal valve. Both from sample MU 36 (Table 1).

Discussion
The suboval outline, poorly impressed muscle scars, small pedicle notch (Fig. 4g) and dorsibiconvex profile of the Murruin Creek specimens are similar to *P. argus* from the Llandovery Želkovice and Wenlock Motol formations of the Czech Republic (Mergl 1999a). The Murruin Creek specimens differ in having a wider limbus that creates a distinctly flattened rim externally, particularly along the posterior margin of the dorsal valve (Fig. 4h). Internally, the ventral valve differs by possessing a prominent, raised, subperipheral rim along the posterior margin (Fig. 4g).

linguloid gen. et sp. indet. 1
Fig. 4l

Figured material
AM F128320 (Fig. 4l): post-larval shell fragment, sample MU 36 (Table 1).

Discussion
Known only from only a few post-larval shell fragments, these specimens have an ornament of low, broadly rounded concentric ridges spaced at regular intervals of 250 μm. The ridges, and concave interspaces, bear closely spaced, rounded concentric filae (six per 100 μm) (Fig. 4l). This is similar to the post-larval shell ornament of *Lingulops austrinus* Valentine, Brock and Molloy, 2003 from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales and *Lingulops barrandei* Mergl, 1999b from the Ludlow Kopanina Formation of the Czech Republic (Mergl 1999b, 2001). In comparison, the concentric ridges of the Boree Creek material are spaced at intervals of 30 μm and the concentric filae of the Czech material are confined to the concentric ridges. No evidence of a muscle supporting platform or limbus, diagnostic features of *Lingulops* Hall, 1872 (Holmer and Popov 2000), were observed.

linguloid gen. et sp. indet. 2
Fig. 4i-k

Figured material
AM F128319 (Fig. 4i-k): dorsal valve, sample MU 35 (Table 1).

Discussion
The well-developed limbus, ?elongate outline and lack of post-larval shell pitting (Fig. 4i, j) suggest affinities with the Elliptoglossinae. Unlike both *Elliptoglossa* Cooper, 1956 and *Lingulops*, the Murruin Creek material has a well-developed, broadly depressed and anacline dorsal valve pseudointerarea (Fig. 4k) and can be further differentiated from *Lingulops* by lacking a muscle supporting platform (Fig. 4j).

Superfamily Discinoidea Gray, 1840
Family Discinidae Gray, 1840
Orbiculoidea d'Orbigny, 1847

Type species
Orbicula forbesii Davidson, 1848.

Orbiculoidea sp.
Fig. 5a-g

Figured material
AM F128324 (Fig. 5a): ventral valve fragment, sample MU 34; AM F128325 (Fig. 5b, c): dorsal valve, sample MU 35; AM F128326 (Fig. 5d, e): dorsal valve, sample MU 32; AM F128327 (Fig. 5f, g): dorsal valve, sample MU 31 (Table 1).

Discussion
Juvenile specimens are subrounded with a straight to weakly convex posterior margin and evenly convex lateral and anterior margins (Fig. 5b). In lateral profile they are weakly convex (Fig. 5c).

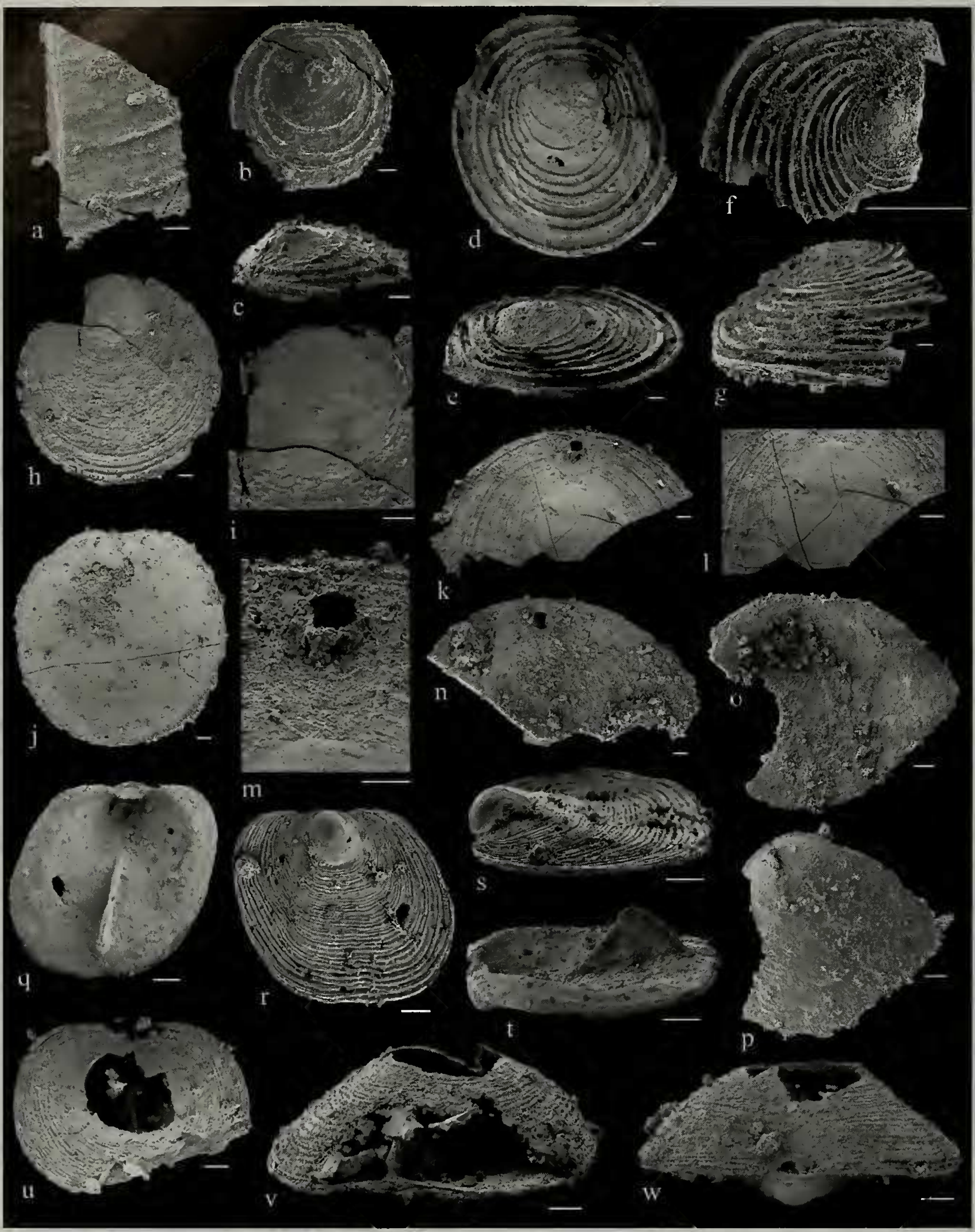


Figure 5. a-g. *Orbiculoidea* sp. all from sample MU 35 unless otherwise mentioned. a. Fragment of ventral valve posterior slope AM F128324, sample MU 34; exterior; b, c. Dorsal valve AM F128325; b, exterior; c, lateral view. d, e. Dorsal valve AM F128326; d, exterior; e, lateral view; f, g. Dorsal valve AM F128327, sample MU 32; f, exterior; g, lateral view. h-n. *Schizotreta* sp. all from sample MU 36. h, i. Dorsal valve AM F128328; h, exterior; i, detail of larval shell. j. Ventral valve AM F128329; interior. k-n Ventral valve AM F128330; k, exterior; l, detail of larval shell; m, detail of pedicle track and foramen; n, interior. o, p. Discinid gen. et sp. indet. 1. o. Dorsal valve AM F128331, sample MU 36; interior. p. Dorsal valve AM F128332, sample MU 35; exterior. q-w. *Artiotreta longisepta* Valentine, Brock and Molloy, 2003. q-t. Dorsal valve AM F128333, sample MU 32; q, interior; r, exterior; and s, lateral views; t, interior in lateral view. u-w. Conjoined valves AM F128334, sample MU 36; u, plan; v, anterior; and w, posterior views. All scale bars equal 100 μm.

Mature dorsal valves are more elongate, with longer, more gently curved, lateral margins (Fig. 5d, f) and are weakly convex to low subconical in lateral profile (Fig. 5e, g). The ventral valves have a long, narrow, parallel-sided pedicle track covered for most of its length by a concave listrum (Fig. 5a). The post-larval shell ornament consists of well-developed concentric ridges arising through insertion on the lateral slopes (Fig. 5b, d, f).

Numerous Silurian discinids have been assigned to *Orbiculoidea* (eg. Biernat 1984; Bassett 1986; Mergl 1996, 2001). These are generally distinguishable from the Murruin Creek specimens by their more circular dorsal valves, greater convexity, and centrally located apices. *Orbiculoidea* sp. C from the Pridoli Požáry and Lochkovian Lochkov formations of the Czech Republic (Mergl, 2001) is similar to the Murruin Creek taxon. Both species have low, subconical dorsal valves with a subcentral apex and an ornament of well-developed concentric ridges arising through insertion on the lateral slopes. *Orbiculoidea* sp. C differs in having a subcircular dorsal valve outline and by being wider and less elongate (Mergl 2001).

Schizotreta Kutorga, 1848

Type species

Orbicula elliptica Kutorga, 1846.

Schizotreta sp.
Fig. 5h-n

Figured material

AM F128328 (Fig. 5h, i): dorsal valve; AM F128329 (Fig. 5j): ventral valve; AM F128330 (Fig. 5k-n): ventral valve. All from sample MU 36 (Table 1).

Discussion

Both valves of this species from Murruin Creek are subcircular with a weakly flattened posterior margin and have a post-larval shell ornament of low, continuous, concentric lamellae (two to four per 100 μm) that become more prominent toward the valve margins (Fig. 5h, k). The large larval shell, located submarginally in the ventral valve (averaging 438 μm long; 500 μm wide) and marginally in the dorsal valve (averaging 354 μm long; 399 μm wide), bear fine growth filae on their anterior and anterolateral slopes (Fig. 5h, k, l). The ventral valve has a short, elliptical pedicle track covered for most of its length by a concave listrum. The foramen, preserved in only one specimen, is quadrate and has a raised rim (Fig. 5k, m). The pedicle track continues internally as a posteriorly directed pedicle tube that is flattened along the valve floor and ends just prior to the posterior margin (Fig. 5n).

Schizotreta elliptica from the Early Ordovician of the Leningrad district in Russia, differs from the Murruin Creek species by its elongately oval dorsal valve, submarginally located larval shell, shorter, more strongly elliptical pedicle track and elliptical foramen. Valentine et al. (2003) described two species of *Schizotreta* from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales. *Schizotreta corrugaticis* Valentine, Brock and Molloy, 2003 has a flatter dorsal valve with a submarginally located larval shell and an ornament of well-developed concentric ridges arising through insertion on the lateral slopes (Valentine et al. 2003). *Schizotreta cristatus* Valentine, Brock and Molloy, 2003 is distinguished by its elongately subrectangular dorsal valve outline and more widely spaced continuous concentric lamellae. Internally, the ventral valve has a low, broad, crescentic-shaped ridge bounding the anterior margin of the muscle field (Valentine et al. 2003). *Schizotreta rarissima* (Barrande, 1879) from the Wenlock Motol Formation of the Czech Republic, has a narrow, elongately oval dorsal valve (Mergl 2001). Biernat (1984) assigned a single dorsal? valve fragment of a discinid, from the Wenlock Podlasie Depression of Poland, to *Schizotreta* which possesses well-developed concentric ridges arising through insertion on the lateral slopes. The ventral valve of *Schizotreta* sp. from the early Llandovery of Wales (Temple 1987), is flatter than the Murruin Creek taxon and has a shorter, posteriorly widening, pedicle track. The concentric lamellae of the Welsh taxon are also more widely spaced (six per mm) and separated by concave interspaces (Temple 1987).

discinid gen. et sp. indet. 1
Fig. 5o, p

Figured material

AM F128331 (Fig. 5o): dorsal valve, sample MU 36; AM F128332 (Fig. 5p): dorsal valve, sample MU 35 (Table 1).

Discussion

This taxon from Murruin Creek has a large (averaging 475 μm long; 500 μm wide), smooth, marginally located dorsal valve larval shell and a post-larval shell ornament of weakly developed, continuous concentric lamellae (Fig. 5p). However, unlike other discinids, the Murruin Creek taxon has a transversely elliptical dorsal valve outline (Fig. 5o, p).

Order Acrotretida Kuhn, 1949
Superfamily Acrotretoidea Schuchert, 1893
Family Scaphelasmatidae Rowell, 1965
Artiotreta Ireland, 1961

Type species

Artiotreta parva Ireland, 1961.

Artiotreta longisepta Valentine, Brock and Molloy, 2003
Figs 5q-w, 6a-d

Synonymy

2003 *Artiotreta longisepta* sp. nov. Valentine, Brock and Molloy, p. 314; pl. 2, figs 9-18.

Description

See Valentine et al. (2003:314).

Figured material

AM F128333 (Fig. 5q-t): dorsal valve, sample MU 32; AM F128334 (Figs 5u-w, 6a): conjoined valves; AM F128335 (Fig. 6b-d): dorsal valve. All from sample MU 36 unless otherwise mentioned (Table 1).

Discussion

The Murruin Creek material is conspecific with *A. longisepta* from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales (Valentine et al. 2003). Some specimens from Boree Creek have a median septum with a slightly thickened posterior margin (see Valentine et al. 2003:pl. 2, fig. 16) and concentric lamellae that tend to be weaker and more irregularly developed (compare Figs 5q, r, 6b with Valentine et al. 2003:pl. 2, figs 11, 13). These minor differences are considered insufficient to exclude conspecificity.

Artiotreta krizi Mergl, 2001 from the Llandovery Želkovice and Wenlock Motol formations of the Czech Republic, has a similar dorsal valve outline to *A. longisepta*, although its anterior margin tends to be more rounded. The median septum of *A. krizi* is also shorter, arising around valve midlength (Mergl 2001:33, pl. 28, fig. 3). *Artiotreta krizi* attains a larger maximum size than *A. longisepta* (up to 1100 µm wide), but most of the material illustrated by Mergl (2001:pl. 28: figs 1, 3, 9, 10) has comparable dimensions (Table 4).

Artiotreta parva from the Wenlock Chimney Hill Limestone (Ireland 1961), Bainbridge Formation (Satterfield and Thompson 1969) and Clarita Formation (Chatterton and Whitehead 1987) of the USA, is distinguished by its rounder dorsal valve outline, shorter median septum arising around valve midlength and finer growth lamellae. *Artiotreta longisepta* is also larger (averaging 538 µm long; 708 µm wide; Table 4) than *A. parva* (averaging 400 µm

Table 4. *Artiotreta longisepta* Valentine, Brock and Molloy, 2003, dorsal valve dimensions (in µm) and ratios.

Artiotreta longisepta Valentine, Brock and Molloy, 2003, dorsal valve dimensions (µm) and ratios									
	L	W	LI	WI	LS	MHS	BS	LP	WP
N	17	43	17	15	18	42	16	17	18
MEAN	533.8	694.8	40.1	255.8	475.0	164.0	245.3	150.7	175.7
SD	106.32	140.85	10.14	46.74	89.22	63.03	32.56	20.48	26.94
MIN	375	400	18.75	150	325	25	212.5	125	150
MAX	675	975	50	312.5	600	287.5	325	175	225

	L/W	LI/WI	WI/W	LS/L	BS/L	LP/WP	LP/L	WP/W
N	17	15	13	15	12	17	12	14
MEAN	83.6%	15.5%	43.4%	88.4%	48.4%	85.8%	30.0%	29.9%
SD	0.08	0.05	0.10	0.04	0.09	0.12	0.07	0.08
MIN	65.8%	9.1%	26.9%	81.3%	36.7%	70.0%	19.2%	18.9%
MAX	98.2%	28.6%	62.5%	93.8%	66.7%	116.7%	38.1%	43.8%

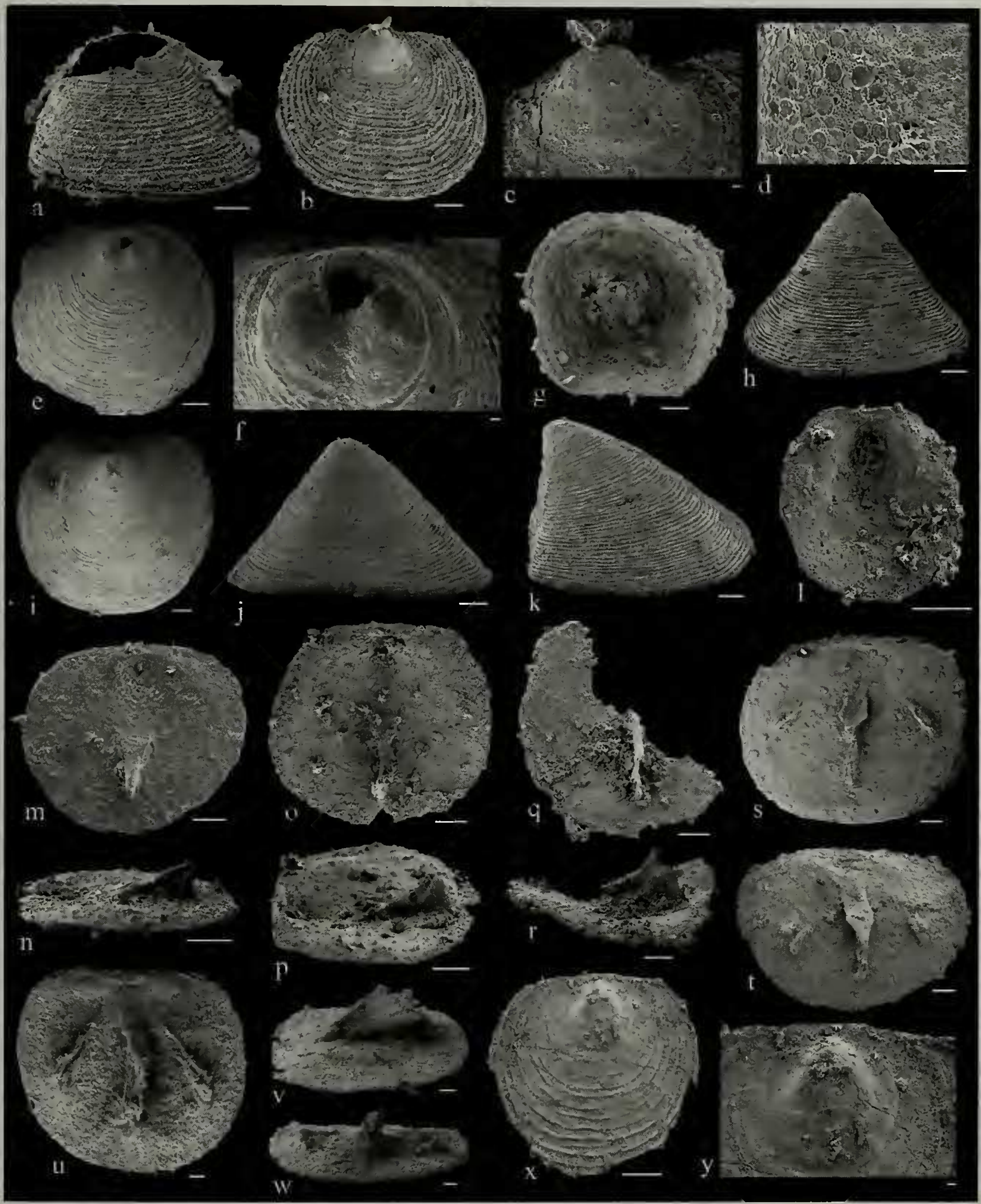


Figure 6. **a-d.** ***Artiotreta longisepta*** **Valentine, Brock and Molloy, 2003 both from sample MU 36. a. Conjoined valves AM F128334; lateral view. b-d. Dorsal valve AM F128335; b, exterior; c, detail of larval shell (scale bar equals 10 μm); d, detail of larval shell microornament (scale bar equals 10 μm). e-y.** ***Acrotretella dizeugosa*** **sp. nov. all from sample MU 31 unless otherwise mentioned. e, f. Ventral valve paratype AM F128336, sample MU 35; e, exterior; f, detail of larval shell (scale bar equals 10 μm). g. Ventral valve paratype AM F128337; interior. h-k. Ventral valve paratype AM F128338, sample MU 35; h, exterior; i, plan; j, posterior; and k, lateral views. l. Dorsal valve paratype AM F128339; interior. m, n. Dorsal valve paratype AM F128340; m, interior; n, lateral view. o, p. Dorsal valve paratype AM F128341; o, interior; p. lateral view. q, r. Dorsal valve paratype AM F128342; q, interior; r, lateral view. s. Dorsal valve paratype AM F128343, sample MU 35; interior. t. Dorsal valve paratype AM F128344, sample MU 32; interior. u-w. Dorsal valve holotype AM F128345, sample MU 32; u, interior; v, lateral; and w, anterior views. x, y. Dorsal valve paratype AM F128346; x, exterior; y, detail of larval shell (scale bar equals 10 μm). Unless otherwise mentioned all scale bars equal 100 μm.**

long; 500 μm wide) (Ireland 1961:1138).

von Bitter and Ludvigsen (1979) documented two sizes of larval shell pits in *A. parva*—a larger set (3-6 μm in diameter) with no cross-cutting relationships and a smaller set (~0.3 μm in diameter) located on flat areas between the larger pits. *Artiotreta longisepta* also possesses two sizes of larval shell pits—a larger set (4-5 μm in diameter) with none to one (occasionally two) orders of cross-cutting and a smaller set (0.2-1 μm in diameter) (Fig. 6d). A smaller set of larval shell pits has not been documented in *A. krizi*.

Family Torynelasmatidae Rowell, 1965
Acrotretella Ireland, 1961

Type species

Acrotretella siluriana Ireland, 1961.

Emended diagnosis

Ventral valve conical to subpyramidal with distinct larval shell and broad, procline to catacline pseudointerarea. Pedicle tube and apical process absent. Dorsal valve flat to weakly convex with distinct, bulbous larval shell. Pseudointerarea broad, anacline, occasionally weakly depressed medially. Median septum low to high with dorsally concave surmounting plate on ventral margin. Anterior margin of median septum with variably developed number of spines and folds depending upon valve size and species. One to two pairs of lateral processes developed either side of dorsal valve median septum in some species.

Discussion

Previous authors (Biernat and Harper 1999, Mergl 2001 and Valentine et al. 2003) have defined species of *Acrotretella* based upon the presence or absence of lateral processes (sensu Biernat and Harper 1999:88) in the dorsal valve (Table 5). Despite both forms having a similar stratigraphic range, no consideration has previously been given to the possibility that the development of lateral processes may be part of an ontogenetic growth continuum. It is only in the Cobra Formation and the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales (Valentine et al. 2003), that *Acrotretella* with and without lateral processes occur in the same stratigraphic horizons (Tables 5, 6). Analysis of the ontogeny of *Acrotretella* has been prevented before because most occurrences are restricted to a handful of specimens (Table 5). A sufficient number of specimens assignable to *Acrotretella dizeugosa* sp. nov. (36 ventral valves and 39 dorsal valves; Table 2) have been recovered from the Cobra Formation to allow the first detailed ontogenetic investigation of *Acrotretella*.

The dorsal valve ontogeny of *A. dizeugosa* can be divided into four overlapping developmental growth stages (Fig. 7): (1) development of a simple dorsal valve median septum with a dorsally concave surmounting plate; (2) growth of spines along the anterior margin of the dorsal valve median septum; (3) insertion of the first pair of lateral processes; and (4) insertion of a second pair of lateral processes posterior of, and parallel to, the first pair. Although considerable overlap exists in the size range of each growth stage, each growth stage generally corresponds with an increase in dorsal valve size (Fig. 7).

During the first dorsal valve growth stage of *A. dizeugosa* (413-725 μm long; 488-788 μm wide) (Fig. 7) a simple, low median septum with surmounting plate is developed (Fig. 6m, n). The surmounting plate originates slightly posterior of valve midlength as two ridges separated by a dorsally concave plate averaging 63 μm wide. A single dorsal valve of *A. dizeugosa* from sample MU 31 (628.6 m above the base of the section) (275 μm long; 288 μm wide) has yet to develop a median septum with surmounting plate (Fig. 6l). The surmounting plate coalesces into a single blade at 56%, and continues to 86%, valve length. The median septum reaches an average height of 75 μm at 81% valve length. The anterior margin of the median septum is steep, straight to weakly curved and smooth (Fig. 6n).

Up to three spines, termed 'septal spines' by Popov (in Nazarov and Popov 1980:75) are developed along the anterior margin of the median septum during the second dorsal valve growth stage (563-763 μm long; 688-838 μm wide) (Fig. 7). The median septum of this growth stage is higher than in the proceeding stage, averaging 144 μm high at 75%, and extends to 87%, valve length. The anterior margin of the median septum is longer and more strongly curved than in the first growth stage (Fig. 6q, r). Septal spines also occur in numerous Ordovician acrotretoids (eg. *Numericoma* Popov, 1980 in Nazarov and Popov 1980). Popov (in Nazarov and Popov 1980) and Holmer (1989) have linked the development of septal spines in such genera to the ontogenetic development of the median septum—from a simple, subtriangular blade in juveniles, to a complexly spinose structure in mature individuals.

The first pair of lateral processes appear during the third dorsal valve growth stage (625-950 μm long; 750-1325 μm wide) (Fig. 7). The lateral processes originate around valve midlength and are initially developed as low, short, anteriorly divergent rods

Table 5. Locality, age, available material and dimensional data for species of *Acrotretella* with and without lateral processes. Abbreviations: vv = ventral valve(s); dv = dorsal valve(s); l = length; w = width. *Average dimensions (in μm based on dimensions given, or on illustrated material, in the accompanying reference.

Acrotretella with lateral process							
Species	Locality	Age	Available material		Average dimensions (μm)*		Reference
			vv	dv	vv	dv	
Acrotretella goldapiensis Biernat and Harper, 1999	Baltic syneclise, Poland	Llanvirn	1	3	too fragmentary	l = 437 w = 591	Biernat and Harper (1999)
Acrotretid gen. et sp. nov. (see text)	Kildare Limestone, Ireland	Ashgill	0	1	-	l = 676 w = 1037	Wright and McClean (1999)
Acrotretella sp. A	Boree Creek Formation - Borenore Formation (B section), Australia	Llandovery - Wenlock	0	18	-	l = 808 w = 963	Dean-Jones (1979)
	Boree Creek Formation (BM section), Australia	Wenlock	0	9	-	l = 900 w = 1127	Valentine et al. (2003)
	Boree Creek Formation (WERR section) and Borenore Formation (DSC/B and BOR/1 sections), Australia	Wenlock	0	2	-	l = 874 w = 1038	Cockle (unpub. data)
Acrotretella triseptata Mergl, 2001	Kotýs Limestone, Czech Republic	Lochkovian	0	2	-	l = 766 w = 858	Mergl (2001)

TABLE 5 CONTINUED ON PAGE 216

Table 5 continued

Acrotretella without lateral processes							
Species	Locality	Age	Available material vv	Available material dv	Average dimensions (μm)* vv	Average dimensions (μm)* dv	Reference
Acrotretella sp.	Dalby Limestone, Sweden	Caradoc	0	2	-	l = 439 w = 509	Holmer (1989)
Acrotretella sp.	Mayatas Formation, Kazakhstan	Caradoc	0	2	-	l = 763 w = 1050	Popov (2000)
Acrotretella sp. a	Bestrop Limestone, Sweden	Ashgill	3	2	l = 380 w = 480	l = 437 w = 520	Holmer (1986)
Acrotretella goodridgei Valentine, Brock and Molloy, 2003	Quarry Creek Limestone, Bridge Creek Limestone and Cobbler's Creek Limestone (E-E' section), Australia	Llandovery	1	6	too fragmentary	l = 558 w = 592	Bischoff (unpub. data)
	Boree Creek Formation (BM section), Australia	Llandovery - Wenlock	26	44	l = 648 w = 859	l = 757 w = 914	Valentine et al. (2003)
	Boree Creek Formation - Borenore Formation (B section), Australia	Llandovery - Wenlock	26	37	l = 730 w = 952	l = 799 w = 937	Dean-Jones (1979)
	Boree Creek Formation (WERR section) and Borenore Formation (DSC and BOR/1 sections), Australia	Wenlock	1	2	l = 850 w = 1075	l = 813 w = 1113	Cockle (1999; unpub. data)
Acrotretella siluriana Ireland, 1961	Chimney Hill Limestone, Hunton Formation, Oklahoma, USA	Wenlock	8	16	l = 660 w = 782	l = 626 w = 689	Ireland (1961)
	Motol Formation, Czech Republic	Wenlock	5	10	l = 843 w = 1030	l = 828 w = 954	Mergl (2001)
Acrotretella sp. A	Lynore Limestone, Australia	Pridoli	0	2	-	l = 900 w = 810	Klyza (1997)
Acrotretella spinosa Mergl, 2001	Požáry Formation, Czech Republic	Pridoli	6	20	l = 735 w = 816	l = 808 w = 939	Mergl (2001)
Acrotretella sp.	Camelford Limestone, Australia	Pridoli	0	6	-	l = 808 w = 937	Farrell (unpub. data)

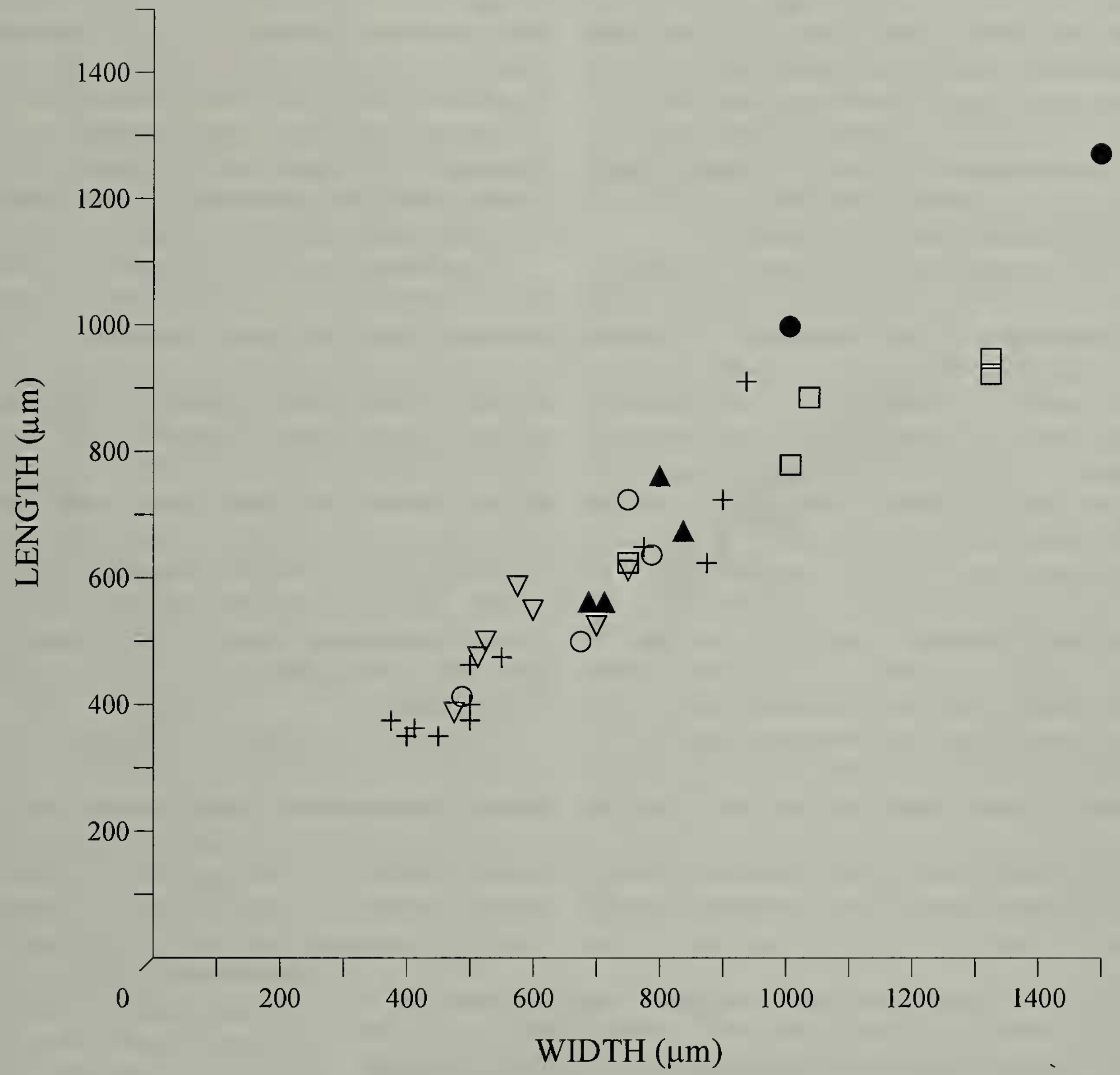


Figure 7. Length versus width for ventral valves and each dorsal valve growth stage of *Acrotretella dizeugosa* sp. nov.

+ = ventral valves (n = 12);

○ = dorsal valve growth stage 1 (n = 4);

▲ = dorsal valve growth stage 2 (n = 4);

∇ = unknown dorsal valve growth stage (n = 7)*;

□ = dorsal valve growth stage 3 (n = 5);

● = dorsal valve growth stage 4 (n = 2).

Note that the dorsal valve median septum of some specimens of A. *dizeugosa* without lateral processes is not preserved. Such specimens, equivalent to dorsal valve growth stages 1 or 2, are presented here as a separate, combined group. See text for discussion on dorsal valve growth stages of *A. dizeugosa.

with rounded anterior margins (Fig. 6s). The median septum of this growth stage is higher again than in the previous growth stages (averaging 188 μm high) and has a long, curved anterior margin with up to four septal spines. A positive relationship between dorsal valve size and the development of septal spines can also be demonstrated in *Acrotretella spinosa* Mergl, 2001 from the Přídolí Formation of the Czech Republic (see Mergl 2001:pl. 26, figs 4-6).

The final dorsal valve growth stage of *A. dizeugosa* (1000-1275 μm long; 1025-1500 μm wide) (Fig. 7) is characterised by the development of a second pair of lateral processes that are inserted posterior of, and parallel to, the first pair at approximately one-third valve length (Fig. 6t, u). Two specimens assignable to this growth stage were recovered from Murruin Creek. The lateral processes of the smaller of these specimens (1000 μm long; 1025 μm wide) are developed as low, slightly elongate rods, with the posterior pair being slightly shorter than the anterior pair. The anterior ends of the first pair are weakly twisted and flattened. The median septum of this specimen was not preserved (Fig. 8t). The posterior pair of lateral processes in the larger of these specimens (1275 μm long; 1500 μm wide) are higher and longer than the anterior pair, and both pairs end in variably developed, stubby projections (Fig. 6u-w). The median septum of this specimen, although damaged, bears the remains of five septal spines along its anterior margin (Fig. 6v, w). Concurrent with this final dorsal valve growth stage is the initiation of folding in the median septum, with up to two folds being developed. Biernat (1973:43) demonstrated a positive relationship between valve size and the degree of folding in the dorsal valve median septum of *Myotreta* Gorjansky, 1969. Although only one specimen of *A. dizeugosa* was recovered with a folded median septum, this feature does occur in the largest specimen suggesting it is also related to valve size.

Apart from *Acrotretella goldapiensis* Biernat and Harper, 1999 from the Llanvirn Baltic syneclise of northwest Poland, no ventral valves have previously been assigned to any species of *Acrotretella* with lateral processes (Table 5) (Mergl 2001; Valentine et al. 2003). Ventral valves assignable to *Acrotretella* from the Cobra Formation co-occur with, and overlap the size range of, each dorsal valve growth stage of *A. dizeugosa* (Fig. 7; Table 6). A similar trend is also observable in *A. goodridgei* Valentine, Brock and Molloy, 2003 from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales (see species discussion for *A. dizeugosa* below) (Fig. 8).

Therefore, a positive relationship can be demonstrated to exist between dorsal valve size and the development of lateral processes and septal spines along the anterior margin of the dorsal valve median septum in *A. dizeugosa* (Fig. 7). Additional material for most *Acrotretella* species is required to confirm if lateral processes, and/or septal spines, were developed in all species (Table 5). Until such time, care must be exercised when relying upon the presence or absence of these features to define species. To this end, an ontogenetic growth continuum for each population of *Acrotretella* should be established prior to the erection of new species and the level of intraspecific variation present determined.

Table 6. Stratigraphic distribution and abundance of ventral valves and each dorsal valve growth stage of *Acrotretella dizeugosa* sp. nov. recovered from productive samples along the MU section through the Cobra Formation in Murruin Creek. *Note that the dorsal valve median septum of some specimens of *A. dizeugosa* without lateral processes is not preserved. Such specimens, equivalent to dorsal valve growth stages 1 or 2, are presented here as a separate, combined group. See text for discussion on dorsal valve growth stages of *A. dizeugosa*.

Metres above base of MU section	628.6	641.3	642.9	643.1	Totals
Sample Numbers *Acrotretella dizeugosa*	31	32	35	36	
ventral valves	25	6	3	2	36
dorsal valve growth stage 1	5		2	2	9
dorsal valve growth stage 2	7				7
dorsal valve growth stage 3		3	2		5
dorsal valve growth stage 4		2			2
unknown dorsal valve growth stage*	11	2	1	2	16

Acrotretella dizeugosa sp. nov.
Figs 6e-y, 9a-b

Etymology

Gr., *di*, two, double; Gr., *zeugos*, team, pair; in reference to the development of two pairs of lateral septa in the dorsal valve of mature individuals.

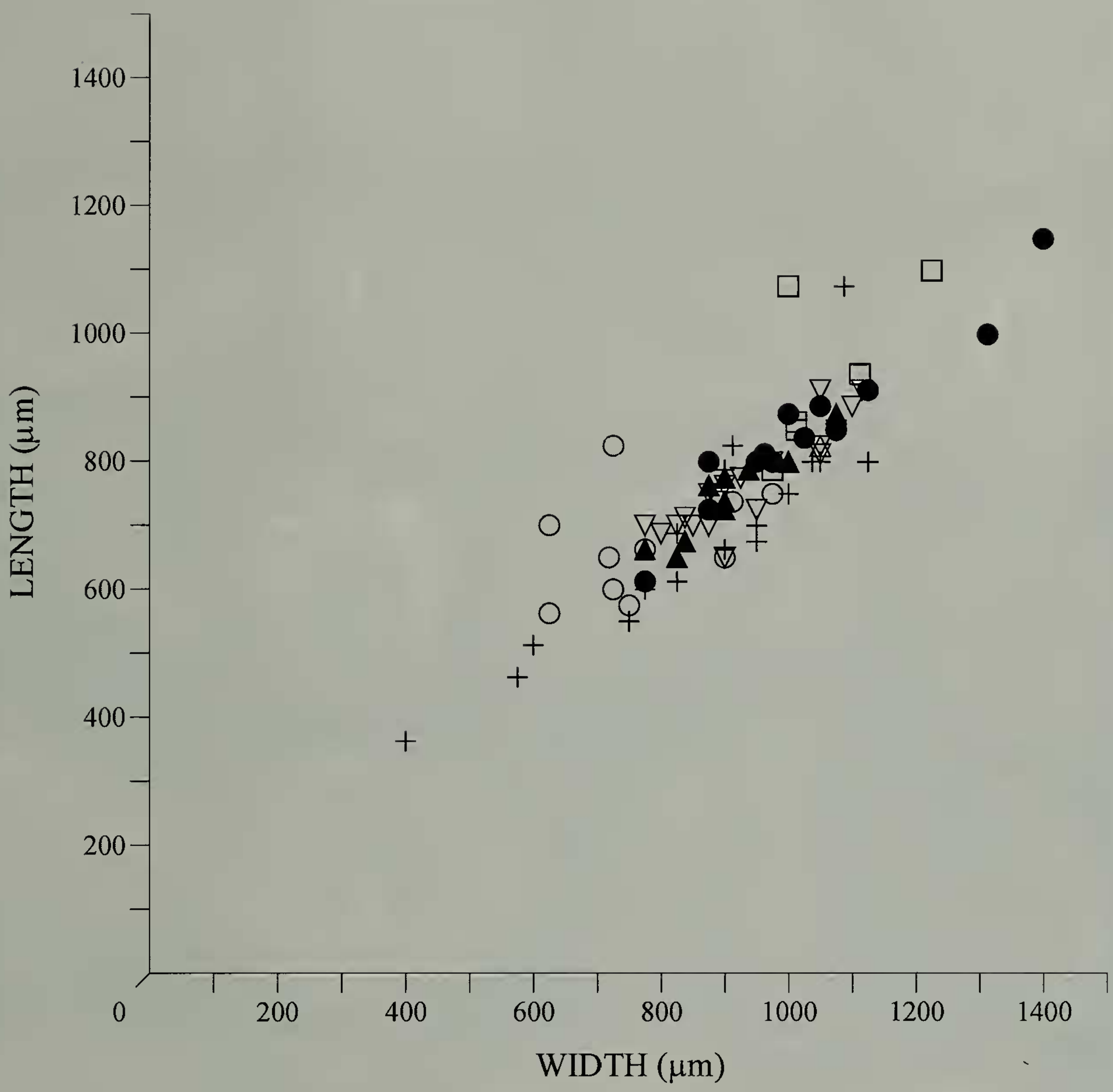


Figure 8. Length versus width for ventral valves and each dorsal valve growth stage of *Acrotretella goodridgei* Valentine, Brock and Molloy, 2003 from the BM section of Valentine et al. (2003) and the B section of Bischoff (1986) through the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales.

+ = ventral valves (n = 17);
○ = dorsal valve growth stage 1 (n = 10);
▲ = dorsal valve growth stage 2 (n = 12);
▽ = unknown dorsal valve growth stage (n = 20)*;
□ = dorsal valve growth stage 3 (n = 6);
● = dorsal valve growth stage 4 (n = 2).

Note that the dorsal valve median septum of some specimens of *A. goodridgei* without lateral processes is not preserved. Such specimens, equivalent to dorsal valve growth stages 1, 2 or 3, are presented here as a separate, combined group. See text for discussion on dorsal valve growth stages of *A. goodridgei.

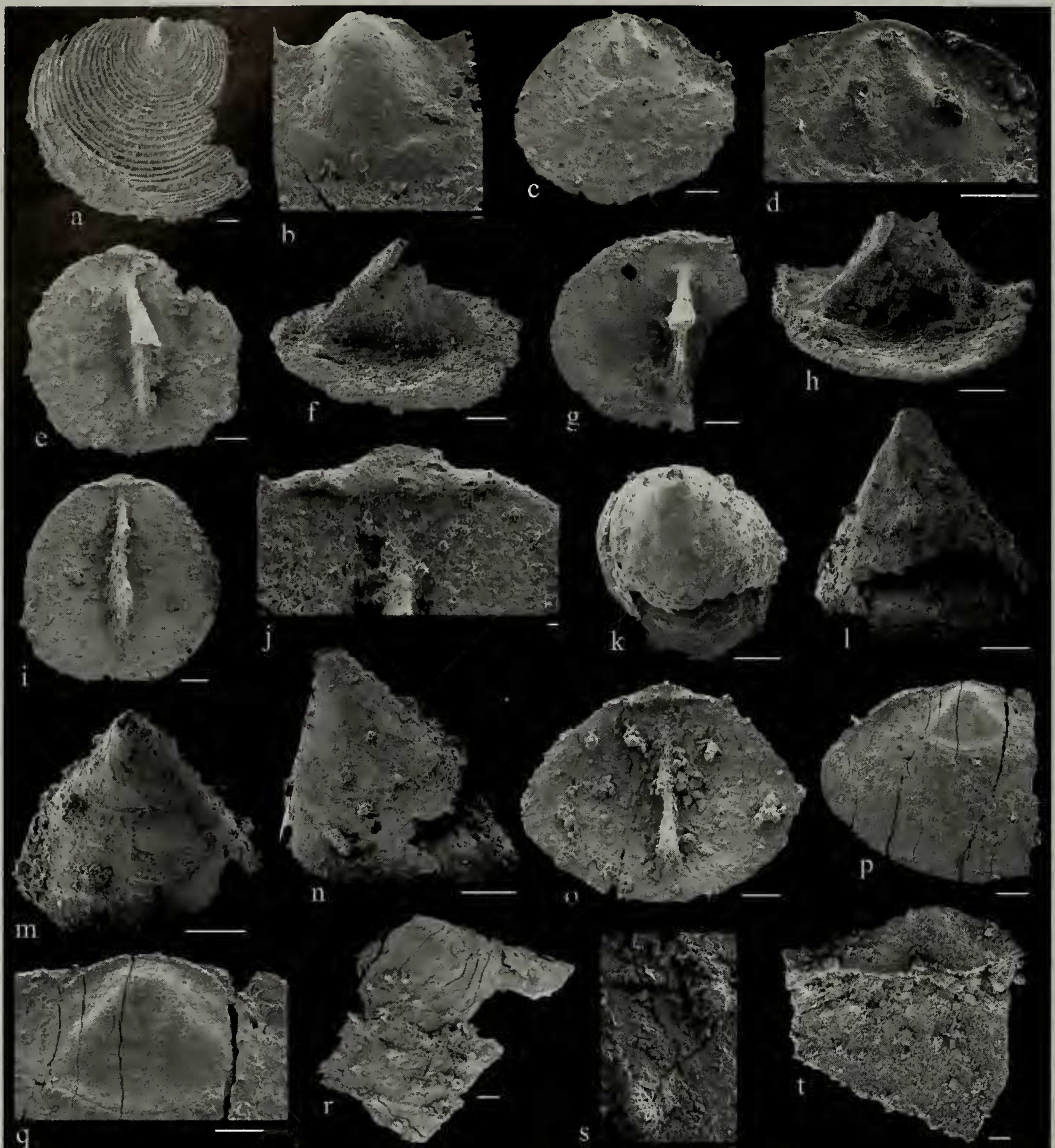


Figure 9. a-b *Acrotretella dizeugosa* sp. nov. Dorsal valve paratype AM F128347, sample MU 31; a, exterior Figure; b, detail of larval shell (scale bar equals 10 μm). c-n. *Opsiconidion ephemerus* (Mergl, 1982) all from sample MU 32 unless otherwise mentioned. c, d. Dorsal valve AM F128348, sample MU 35; c, exterior; d, detail of larval shell. e, f. Dorsal valve AM F128349; e, interior; f, lateral view. g, h. Dorsal valve AM F128350; g, interior; h, lateral view. i, j. Dorsal valve AM F128351; i, interior; j, detail of pseudointerarea. k-n. Ventral valve AM F128352; k, exterior; l, anterior; m, posterior; and n, lateral views. o-q. *Opsiconidion* sp. o. Dorsal valve AM F128353, sample MU 31; interior. p, q. Dorsal valve AM F128354, sample MU 36; p, exterior; q, detail of larval shell. r-t. Siphonotretid gen. et sp. indet. 1. r, s. Dorsal valve AM F128355, sample MU 36; r, exterior; s, detail of spines (scale bar equals 10 μm). t. Dorsal valve AM F128356, sample MU 34; interior. Unless otherwise mentioned all scale bars equal 100 μm.

Table 7. ***Acrotretella dizeugosa*** **sp. nov., ventral and dorsal valve dimensions (in μm) and ratios.**

Acrotretella dizeugosa sp. nov., ventral valve dimensions (μm) and ratios	L	W	H	Fp	Fa	Fw	M	HP	LP	WP
N	12	15	15	12	17	18	15	17	19	20
MEAN	505.2	655.0	344.2	85.4	36.8	33.0	117.5	84.6	164.3	190.6
SD	182.35	240.99	171.45	61.67	8.53	9.05	62.11	26.34	20.55	31.64
MIN	350	375	125	37.5	25	25	50	50	125	150
MAX	912.5	1150	675	275	56.25	50	275	150	225	262.5

	L/W	H/L	M/L	LP/WP	LP/L	WP/W	HP/H	HP/LP
N	12	9	12	18	12	13	13	14
MEAN	85.0%	55.5%	22.8%	88.8%	36.0%	32.3%	31.2%	47.5%
SD	0.09	0.13	0.10	0.07	0.12	0.12	0.15	0.11
MIN	71.4%	35.7%	9.6%	75.0%	17.8%	15.2%	10.3%	28.6%
MAX	100.0%	75.0%	44.0%	108.3%	50.0%	48.5%	43.8%	66.7%

Acrotretella dizeugosa sp. nov., dorsal valve dimensions (μm) and ratios	L	W	LI	WI	OSP	LSP	WSP	LS	MHS	LP	WP
N	22	31	27	19	29	19	28	24	13	29	31
MEAN	678.4	763.3	50.7	388.2	234.5	375	81	592.2	110.6	163.4	161.3
SD	218.57	244.58	28.61	152.04	28.08	71.32	27.82	172.42	54.21	16.68	25.28
MIN	275	287.5	12.5	100	187.5	250	50	350	50	125	112.5
MAX	1275	1500	125	725	275	575	150	1075	187.5	200	200

	L/W	LI/WI	WI/W	LS/L	LSP/L	OSP/L	LSP/LS	LP/L	WP/W	LP/WP
N	22	19	17	19	14	20	16	18	24	29
MEAN	84.1%	13.7%	47.7%	82.8%	55.6%	37.0%	69.7%	26.7%	22.6%	104.6%
SD	0.09	0.06	0.07	0.07	0.09	0.11	0.11	0.06	0.06	0.21
MIN	69.8%	6.3%	34.6%	70.0%	42.3%	17.7%	53.5%	15.8%	11.3%	76.9%
MAX	97.9%	30.8%	54.8%	90.2%	68.4%	52.6%	89.3%	68.2%	60.9%	133.3%

Type material

Holotype: AM F128345 (Fig. 6u-w): dorsal valve, sample MU 32. Figured paratypes: AM F128336 (Fig. 86, f): ventral valve, sample MU 35; AM F128337 (Fig. 6g): ventral valve; AM F128338 (Fig. 6h-k): ventral valve, sample MU 35; AM F128339 (Fig. 6l): dorsal valve; AM F128340 (Fig. 6m, n): dorsal valve; AM F128341 (Fig. 6o, p): dorsal valve; AM F128342 (Fig. 6q, r): dorsal valve; AM F128343 (Fig. 6s): dorsal valve, sample MU 35; AM F128344 (Fig. 6t): dorsal valve, sample MU 32; AM F128346 (Fig. 6x, y): dorsal valve; AM F128347 (Fig. 9a, b): dorsal valve. All from sample MU 31 unless otherwise mentioned (Table 1).

Type horizon and locality

Sample MU 32 (Fig. 3), Ludlow (?*siluricus* Zone), upper part of the Cobra Formation cropping out in Murruin Creek (Fig. 2), Taralga Group, southeastern New South Wales, Australia (Fig. 1).

Diagnosis

A species of *Acrotretella* with numerous, closely spaced growth lamellae on the ventral valve (eight per 100 μm), but more widely spaced on the dorsal valve (three to five per 100 μm). Dorsal valve larval shell with rounded, variably developed, medially depressed ridge bounding anterior and anterolateral margins. Anterior margin of dorsal valve median septum bearing up to two folds and five septal spines. Two pairs of lateral processes inserted centrally, either side of dorsal valve median septum, in mature individuals.

Description

Ventral valve subpyramidal, subtending apical angle of 85° in anterior view. In lateral profile posterior slope straight to weakly convex; anterior slope long, flat to weakly convex. Valve height (Table 7) averaging 56% valve length and 46% valve width.

Beak directed ventrally. Pseudointerarea catacline to weakly apsacline, subtending apical angle of approximately 80°, separated from remainder of valve by gentle flexure. Intertrough vaguely defined in some specimens, subtending apical angle of approximately 20°. Larval shell subcircular, averaging 164 μm long, 191 μm wide, 85 μm high. Foramen confined to larval shell, subcircular, averaging 37 μm long and 33 μm wide. Narrow, subparallel sulcus extending anteriorly from foramen, dividing larval shell into two lateral swellings, occasionally continuing into juvenile portion of post-larval shell. Larval shell bearing shallow, circular, flat-bottomed pits averaging 5 μm in diameter. Post-larval shell ornament of well-defined, closely spaced, continuous concentric lamellae (eight per 100 μm) with rounded crests. Concentric lamellae on juvenile portion of post-larval shell less well-defined. Lamellae becoming disordered and less distinct on pseudointerarea, especially across intertrough.

Ventral valve interior of some specimens with weakly impressed, elongate adductor scars on posterior slope. No other muscle scars or mantle canal patterns observed. Pedicle tube and apical process absent.

Dorsal valve outline subquadrate to transversely elongate, with straight posterior margin, weakly to strongly curved lateral margins, and straight to weakly curved anterior margin. Maximum width occurring slightly posterior of valve midlength. Anterior slope of juveniles long and flat in lateral profile, becoming depressed medially and raised anteriorly in mature specimens. In anterior view, lateral slopes of juveniles short and flat, developing raised margins in mature specimens. Larval shell bulbous, subcircular, averaging 163 μm long and 161 μm wide, with flattened lateral and posterior margins and separated from post-larval shell by raised rim. Larval shell with rounded, variably developed, medially depressed ridge bounding anterior and anterolateral margins. Pitted larval shell microornament similar to that of ventral valve. Post-larval shell ornament similar to that of ventral valve, but concentric lamellae more widely spaced (three to five per 100 μm) separated by flat interspaces bearing finer growth filae.

Dorsal valve interior with anacline pseudointerarea extending approximately 50% valve width. Median plate broadly subtriangular, weakly depressed medially, merging almost imperceptibly with propareas laterally. Anterior margin of pseudointerarea raised slightly above valve floor medially. Cardinal muscles scars weakly impressed, suboval, located posterolaterally, extending anteriorly approximately one-third valve length. Anterocentral muscle scars and mantle canal patterns not observed. Median septum subtriangular in lateral profile, extending 83% valve length, bearing dorsally concave surmounting plate on posterior margin for 70% of length. Surmounting plate originating slightly posterior of valve midlength as two ridges, separated by dorsally concave plate, merging into single blade at 56% valve length. Anterior margin of median septum bearing up to two folds and five hollow, septal spines. Two pairs of lateral processes developed centrally in mature individuals—first pair originating slightly posterior of valve midlength; second pair posterior of, and parallel to, first pair, originating at approximately one-third valve length. Both pairs of lateral processes initially developed as low, rounded, anteriorly divergent (at approximately 90°) rods with rounded anterior margins. Lateral processes becoming longer and higher anteriorly with increasing valve size, extending to 60% valve length. Stubby projections variably developed along anterior margins of both pairs of lateral processes. Second pair of lateral septa in mature specimens longer and higher than first pair.

Discussion

Mature dorsal valves of *Acrotretella dizeugosa* are easily distinguished from other *Acrotretella* by the development of two pairs of centrally located lateral processes (Fig. 6t, u). In comparison, most other *Acrotretella* with lateral processes only possess a single pair. The closely spaced concentric lamellae (eight per 100 μm) on the ventral valve of *A. dizeugosa* (Fig. 6e, h-k), and the variably developed low, rounded, medially depressed ridge bounding the anterior and anterolateral margins of the dorsal valve larval shell (Figs 6y, 9b), are also unique to the species.

Wright and McClean (1991: fig.1 H-I) figured a single acrotretoid dorsal valve from the Ashgill Kildare Limestone of Ireland with two pairs of lateral processes and a complexly folded median septum bearing a dorsally concave surmounting plate along its ventral margin. Although Wright and McClean (1991) referred to this specimen as a new, but unnamed, acrotretid genus, these features suggest assignment to *Acrotretella*. However, unlike *A. dizeugosa*, the Irish taxon has a transversely oval dorsal valve outline and both pairs of lateral processes are located posteromedially (Wright and McClean 1991).

Valentine et al. (2003) recognised two species of *Acrotretella* in the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales—*Acrotretella goodridgei* (without lateral processes) and *Acrotretella* sp. A (with lateral processes) (Table 5). Recovery of additional specimens of *A. goodridgei* from the Boree Creek Formation and study of Dean-Jones' (1979) material, indicates that *A. goodridgei* passed through a similar ontogenetic growth continuum to *A. dizeugosa* (Fig. 8). *Acrotretella* sp. A is therefore considered synonymous with *A. goodridgei* herein. The first two ontogenetic dorsal valve growth stages of *A. goodridgei* are similar to those of *A. dizeugosa*. The third dorsal valve growth stage of *A. goodridgei* differs in developing a folded dorsal valve median septum, prior to the development of lateral processes. Valentine et al. (2003) believed that the folded dorsal valve median septum of *Acrotretella* was restricted to individuals with lateral processes, but the additional material from the Boree Creek Formation indicates this feature can also occur in specimens without lateral processes. *Acrotretella goodridgei* developed only a single pair of centrally located lateral processes during the fourth dorsal valve growth stage (Fig. 10). However, one damaged, gerontic dorsal valve (1625 μm wide) with a highly folded median septum and well-developed lateral processes, possesses a secondary pair of lateral processes inserted anteromedially, midway between the median septum and the first pair of lateral processes (see Valentine et al. 2003:pl. 2, fig. 26). *Acrotretella goodridgei* is also distinguished by having up to six septal spines and four folds along the anterior margin of the dorsal valve median septum in mature individuals.

Family Biernatidae Holmer, 1989
Opsiconidion Ludvigsen, 1974

Type species

Opsiconidion arcticon Ludvigsen, 1974.

Opsiconidion ephemerus (Mergl, 1982)
Fig. 9c-n

Synonymy

See Mergl (2001:33) plus the following:

1984 *Opsiconidion podlasiensis* n. sp. Biernat, p. 97; pl. 26, figs 1a-c, 2; pl. 27, fig. 1a-e; pl. 28, figs 1a-c, 2a, b, 3; pl. 29, figs 2a, b, 3; pl. 30, figs 1, 2, 3a, b; pl. 31, figs 1a-c, 2.

2003 *Opsiconidion ephemerus* (Mergl); Williams; pl. 2, fig. 2.

Description

See Mergl (1982:115).

Figured material

AM F128348 (Fig. 9c, d): dorsal valve, sample MU 35; AM F128349 (Fig. 9e, f): dorsal valve; AM F128350 (Fig. 9g, h): dorsal valve; AM F128351 (Fig. 9i, j): dorsal valve; AM F128352 (Fig. 9k-n): ventral valve. All from sample MU 32 unless otherwise mentioned (Table 1).

Discussion

The Murruin Creek material is characterised by a subcircular dorsal valve outline with maximum width occurring around valve midlength. The dorsal valve pseudointerarea is anacline and broadly subtriangular with a shallowly depressed median plate bearing fine growth lines. The anterior margin of the pseudointerarea is weakly arcuate (occasionally straight) and raised above the valve floor (Fig. 9c, e, g, i, j). These features are identical to *O. ephemerus* (Mergl 1982, 2001) and *O. podlasiensis* from the Wenlock Podlasie Depression of Poland (Biernat 1984). Biernat (1984) noted variations in the dorsal valve outline, and in the height and width of the dorsal valve pseudointerarea of *O. podlasiensis*. Similar variations also occur in the dorsal valve outline and pseudointerarea of the Australian (Fig. 9c, e, g, i, j) and Czech material (see Mergl 1982:pl. 1, figs 5, 6, 8-11).

The dorsal valve holotype of *O. ephemerus* is 700 μm long and 700 μm wide, and Mergl (1982:116) noted dimensional uniformity within his population. Biernat (1984:97) listed the dimensions of the dorsal valve holotype of *O. podlasiensis* as 690 μm long and 840 μm wide. On average, the Australian material is smaller, only 553 μm long and 622 μm wide, but its size range encompasses both the Czech and Polish material (Table 8). Ventral valves of the type material of *O. ephemerus* and *O. podlasiensis* are strongly conical and can reach over 1000 μm in height. In comparison, the most complete ventral valve of the Australian material is only 475 μm high and not as strongly conical (Fig. 9k-n).

The larval shell microornament of *O. ephemerus* and *O. podlasiensis* consists of circular, flat-bottomed pits (3-6 μm in diameter) with few, or no, cross-cutting relationships (Fig. 11d). This differs from the more commonly observed cross-cutting type of larval shell pitting observed in *Opsiconidion*. The Czech and Polish material also possess a smaller set of pits (0.3-0.5 μm in diameter) located on the smooth, level areas between the larger pits. No evidence of a smaller set of pits were observed in the Murruin Creek specimens (Fig. 9d).

Dorsal valves of *Opsiconidion simplex* Mergl, 2001 from the Pridoli Požáry Formation of the Czech Republic, have a rounder outline than *O. ephemerus* and a median septum that is consistently shorter

Table 8. *Opsiconidion ephemerus* (Mergl, 1982), ventral and dorsal valve dimensions (in μm) and ratios.

Opsiconidion epmemerus (Mergl, 1982), ventral valve dimensions (μm) and ratios							
	Fa	Fw	HP	LP	WP	LP/WP	HP/LP
N	17	17	20	20	18	17	19
MEAN	29.8	29.8	147.4	159.4	174.6	91.9%	92.4%
SD	7.82	7.82	26.65	18.97	20.4	0.13	0.15
MIN	18.75	18.75	110	125	137.5	71.4%	62.9%
MAX	50	50	187.5	187.5	225	115.4%	115.4%

Opsiconidion ephemerus (Mergl, 1982), dorsal valve dimensions (μm) and ratios									
	L	W	LI	WI	LS	MHS	BS	LP	WP
N	54	58	53	54	51	16	61	62	61
MEAN	553.2	622.0	30.7	214.1	473.3	204.7	85.7	180.4	195.1
SD	94.86	112.64	9.90	46.39	85.92	53.23	15.95	31.58	25.95
MIN	287.5	362.5	12.5	112.5	250	75	50	100	150
MAX	750	850	50	325	675	287.5	125	275	250

	L/W	LI/WI	WI/W	LS/L	BS/L	LP/WP	LP/L	WP/W
N	49	49	42	48	47	59	48	47
MEAN	89.8%	14.8%	34.0%	86.2%	16.5%	92.9%	34.4%	32.8%
SD	0.09	0.05	0.07	0.05	0.04	0.12	0.08	0.07
MIN	71.9%	6.3%	24.0%	65.2%	9.6%	57.1%	19.1%	17.4%
MAX	111.6%	28.6%	55.3%	95.2%	30.4%	121.4%	65.2%	62.1%

(only 65-70% valve length) and lower compared to other members of the genus (see Mergl 2001:pl. 30, figs 6, 7, 9-13). *Opsiconidion aldridgei* (Cocks, 1979) from the Llandovery of the Welsh Borderlands (Cocks 1979), the Llandovery-Wenlock of Saaremaa Island, Estonia (Popov 1981) and the Llandovery-Wenlock of the Boree Creek Formation near Orange in central-western New South Wales (Valentine et al. 2003) has a similar subcircular dorsal valve outline to *O. ephemerus*, but has a shorter dorsal valve pseudointerarea with a straight anterior margin and a well-defined median plate. The dorsal valve pseudointerarea of *O. angustus* Valentine, Brock and Molloy, 2003 from the Llandovery-Wenlock Boree Creek Formation near Orange in central-western New South Wales, extends approximately 40% valve width and has an arcuate anterior margin and an indistinct median plate. *Opsiconidion angustus* also has a transversely suboval dorsal valve outline (Valentine et al. 2003).

Opsiconidion sp.

Fig. 9o-q

Synonymy

cf. 1999 *Opsiconidion* sp. Cockle; pl. 5, fig. 15.

cf. 2003 *Opsiconidion* sp. A Valentine, Brock and Molloy, p. 317; pl. 3, figs 16, 17.

Figured material

AM F128353 (Fig. 9o): dorsal valve, sample MU 31; AM F128354 (Fig. 9p, q): dorsal valve, sample MU 36 (Table 1).

Discussion

The Murruin Creek specimens differ from most *Opsiconidion* by their transversely elliptical dorsal valve outline (Fig. 9o, p). The anacline dorsal valve pseudointerarea is broadly subtriangular with a weakly depressed median plate and a straight anterior margin that is raised above the valve floor (Fig. 9o). The median septum is low and subtriangular in lateral profile. Elliptical *Opsiconidion* also occur in the Wenlock Borenore Limestone near Orange in central-western New South Wales (Cockle 1999; Valentine et al. 2003). The Borenore specimens have a dorsal valve pseudointerarea with a more strongly depressed median plate and a gently arcuate anterior margin, but insufficient material is currently available from both localities to determine if these differences are significant. Mergl (2001) also documented an elliptical *Opsiconidion*, *Opsiconidion* sp. A, from the Llandovery Želkovice Formation of the Czech Republic. The Czech material is not as strongly elliptical as the Murruin Creek specimens (compare Fig. 9o, p with Mergl 2001:pl. 29, figs 9, 12) and has a dorsal valve pseudointerarea with a more strongly depressed median plate.

Order Siphonotretida Kuhn, 1949
Superfamily Siphonotretidae Kutorga, 1848
Family Siphonotretidae Kutorga, 1848

siphonotretid gen. et sp. indet. 1
Fig. 9r-t

Figured material

AM F128355 (Fig. 9r, s): dorsal valve, sample MU 36 (Fig. 3); AM F128356 (Fig. 9t): dorsal valve, sample MU 34 (Table 1).

Discussion

The Murruin Creek siphonotretid differs from *Orbaspina* in lacking a pitted post-larval shell and possesses erect spines that are scattered evenly across the valve surface (Fig. 9r). Schizambonine sp. B from the Pragian Praha Formation of the Czech Republic also lacks a pitted post-larval shell, but is distinguished by its well-developed dorsal valve sulcus and prostrate spines that tend to be restricted to the valve margins (Mergl 2001:pl. 36, figs 11-13). Acanthambonine sp. from the Pragian Dvorce-Prokop Limestone of the Czech Republic, whilst also lacking a pitted post-larval shell, has more widely spaced, suberect spines and a submarginal dorsal valve larval shell (Mergl 2001:pl. 36, figs 1, 4, 5-7). Little is known concerning the internal morphology of any of these species. The apsacline dorsal valve pseudointerarea of the Murruin Creek siphonotretid is well-developed and shelf-like (Fig. 9t), similar to the dorsal valve pseudointerarea of *Orbaspina*.

Phylum Conodonta Pander, 1856

Genus *Belodella* Ethington, 1959

Type species

Belodus devonicus Stauffer, 1940.

Belodella anomalis Cooper, 1974
Fig. 10a-i

Synonymy

See Farrell (2004:947) plus the following:
1993 *Belodella* sp. aff. *B. anomalis* Cooper; Simpson et al., p. 153; fig. 4J.

Figured material

AM F128283 (Fig 10a): Sb element; AM F128284 (Fig. 10b): Sb element; AM F128285 (Fig. 10c): Sb element; AM F128286 (Fig. 10d): Sd element; AM F128287 (Fig. 10e): Sc element; AM F128288 (Fig. 10f): t element; AM F128289 (Fig. 10g): fragment of ?t element; AM F128290 (Fig. 10h): M element; AM F128291 (Fig. 10i): M element. All from sample MU 34 (Table 2).

Description

See Farrell (2004:948).

Discussion

This species from Murruin Creek is reconstructed recognising all five elements recorded by Farrell (2004), ie. Sa, Sb, Sc, Sd and 't' or tortiform elements, plus an adenticulate M element. The presence of the adenticulate M element in reconstructions of the genus has been discussed by Barrick and Klapper (1992) and is often still recognisable in small collections (eg. Mawson et al. 1995). The M element of *B. anomalis* (Fig. 10h, i) is more strongly curved than the M element of *Belodella resima* (see Mawson et al. 1995: pl. 4, fig 1.) and *Belodella* cf. *B. resima* (see Barrick and Klapper 1992:pl. 1, fig. 7) and is more robust and broad-based than the M element of *Belodella anfracta* (see Barrick and Klapper 1992:pl. 1 fig. 9).

Cooper (1974) established the diagnostic characteristic of *B. anomalis* as the denticulated anterior margin, but also noted the distinctive apical 'fan-like' structure of denticles. Simpson et al. (1993: fig. 4J) illustrated a specimen from the Cowombat Formation at Cowombat Flat in eastern Victoria lacking the distinctive fan-like denticulation near the cusp and assigned it, with some doubt, to *B. anomalis*. It is now included within the species concept because the serrated nature of the anterior margin represents putative denticulation.

Genus *Coryssognathus* Link and Druce, 1972

Type Species

Cordylodus? *dubius* Rhodes, 1953.

Coryssognathus dubius (Rhodes, 1953)
Fig. 11e, f

Synonymy

See Simpson and Talent (1995:163) and Farrell (2004:959), plus the following:
2002 *Coryssognathus dubius* (Rhodes); Talent et al.; pl. 2, figs U-W; pl. 4, figs F, G.

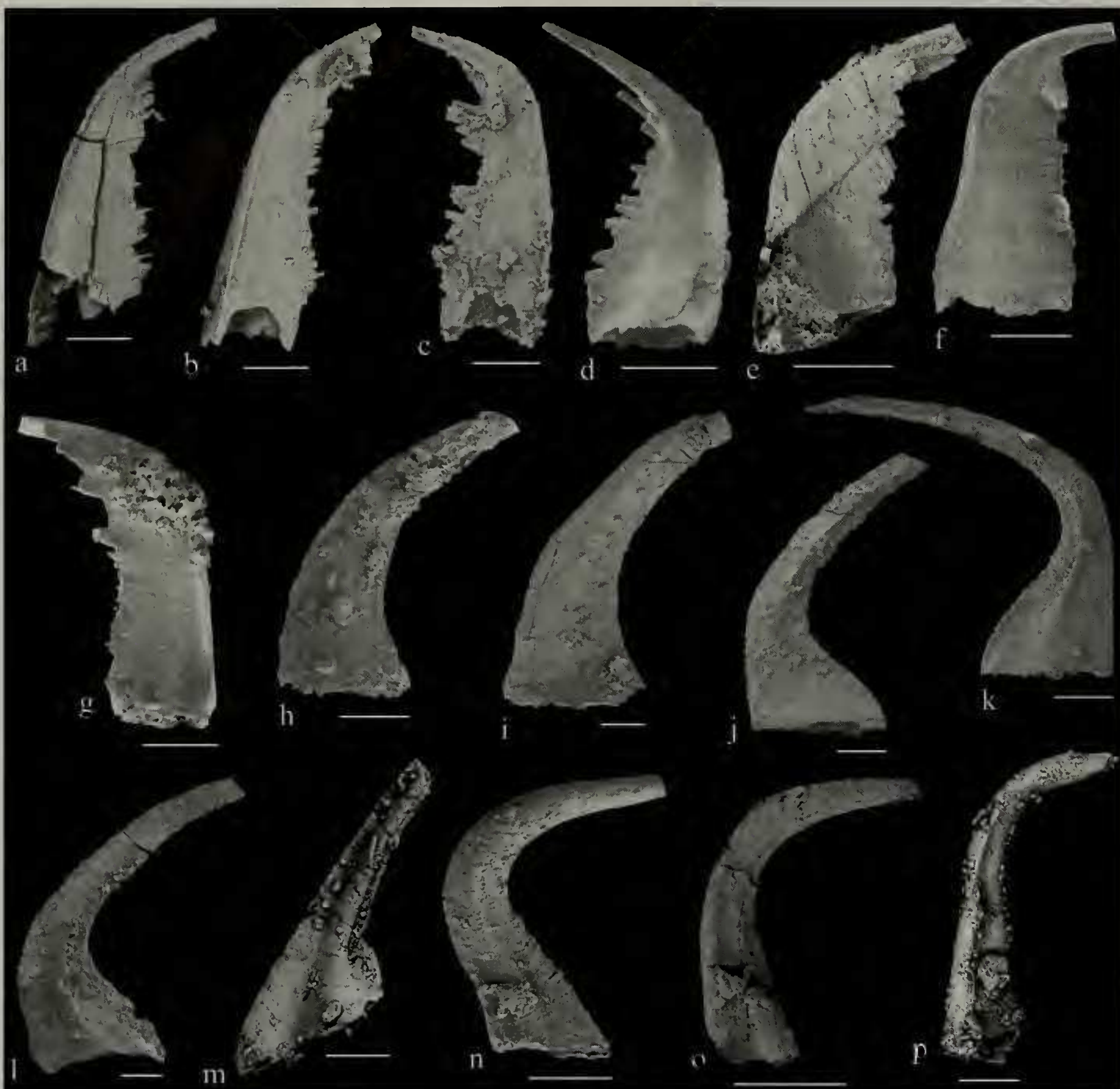


Figure 10. a-i. *Belodella anomalis* Cooper, 1974, all from sample MU 34. a. Sb element AM F128283; lateral view. b. Sb element AM F128284; lateral view. c. Sb element AM F128285; lateral view. d. Sd element AM F128286; lateral view. e. Sc element AM F128287; lateral view. f. t element AM F128288; lateral view. g. fragment of ?t element AM F128289; lateral view; h. M element AM F128290; lateral view. i. M element AM F128291; lateral view. j-l. *Dapsilodus obliquicostatus* (Branson and Mehl, 1933) all from sample MU 37 unless otherwise mentioned. j. M element AM F128292; lateral view. k. M element AM F128293, sample MU 38; lateral view. l. M element AM F128294; lateral view. m. *Decoriconus fragilis* (Branson and Mehl, 1933). Sc element AM F128295, sample MU 34; lateral view. n, o. *Panderodus recurvatus* (Rhodes, 1953), both from sample MU 34. n. Sc element AM F128296; lateral view. o. Sb element AM F128297; lateral view. p. *Panderodus unicostatus* (Branson and Mehl, 1933). M element AM F128302, sample MU 34; lateral view. All scale bars equal 100 μm.

Description

See Miller and Aldridge (1993:246).

Figured material

AM F128303 (Fig. 11e): Pa element; AM F128304 (Fig. 11f): partly preserved Sb element. Both from sample MU 34 (Table 2).

Discussion

The partially preserved Sb element from Murruin Creek has a prominent cusp and the remains of a lateral

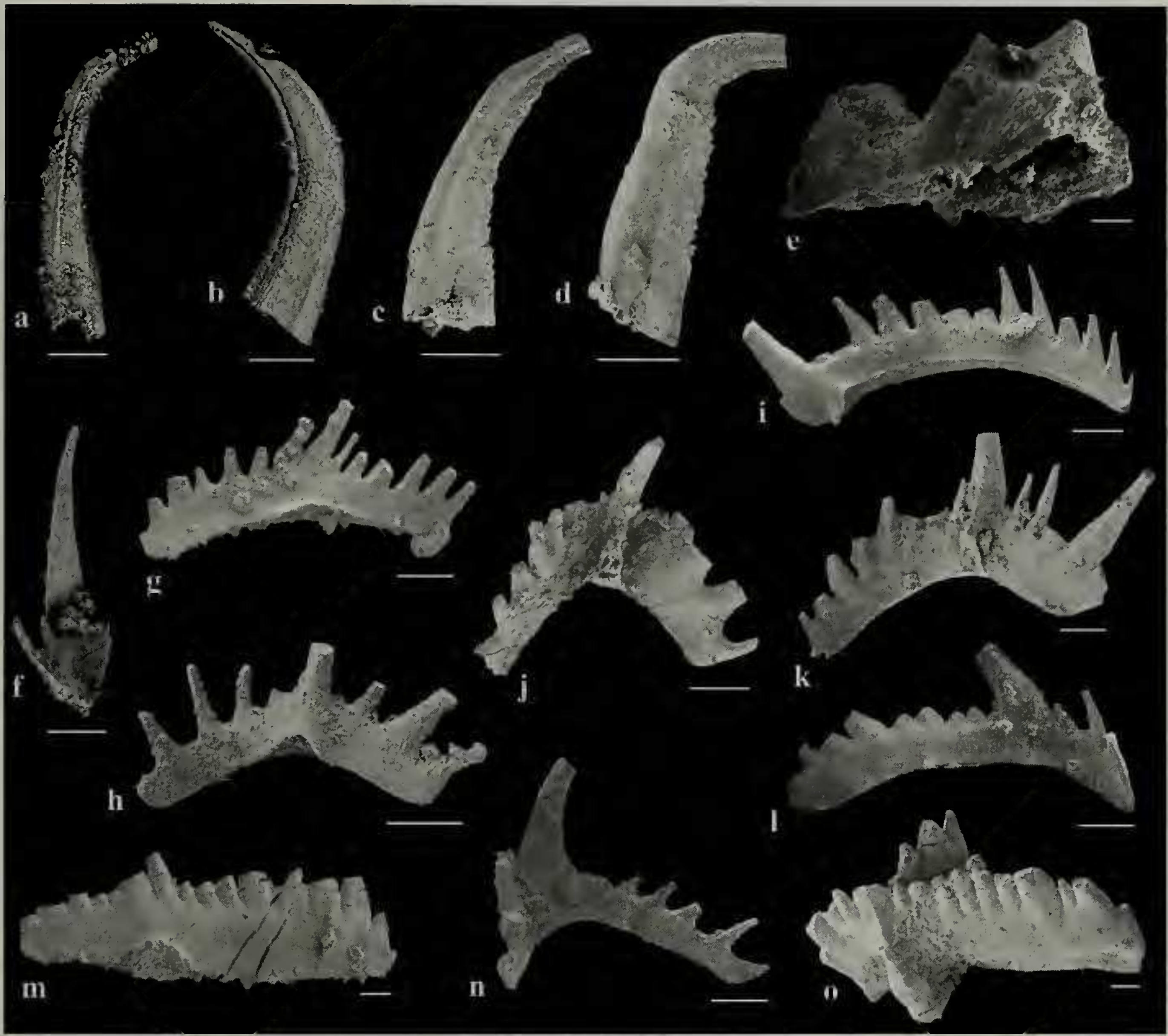


Figure 11. a, b. *Panderodus unicostatus* (Branson and Mehl, 1933), both from sample MU 34. a. Sa element AM F128300; lateral view. b. M element AM F128301; lateral view. c, d. Panderodus serratus Rexroad, 1967, both from sample MU 34. c. Sc element AM F128299; lateral view. d. Sb element AM F128298; lateral view. e, f. *Coryssognathus dubius* (Rhodes, 1953), both from sample MU 34 e. Pa element AM F128303; lateral view. f. Partly preserved Sb element AM F128304; lateral view. g, h. *Oulodus* sp. cf. *Oulodus elegans* (Walliser, 1964), both from sample MU 34. g. Sb element AM F128305; lateral view. h. Sa element AM F128306; lateral view. i-m. *Ozarkodina excavata excavata* (Branson and Mehl, 1933) all from sample MU 34 unless otherwise mentioned. i. M element AM F128307, sample MU 38; inner lateral view. j. Sa element AM F128308; lateral view. k. Sb element AM F128309; inner lateral view. l. Sc element AM F128311; inner lateral view. m. Pa element AM F128310; lateral view. n, o. *Kockelella maenniki* Serpagli and Corradini, 1998, both from sample MU 34. n. Sc element AM F128312; inner lateral view. o. Pa element AM F128313; oblique upper view. All scale bars equal 100 μm.

process bearing a single denticle adjacent to the break in the lateral process. The cusp is evenly curved toward the posterior and tapers evenly toward the apex. The denticulate process projects downward from a broad 'dished' area at the base of the cusp. The basal margin of the process curves toward the anterior from the 'dished' area (Fig. 11f). The poorly preserved scaphate Pa element has an erect, triangular cusp only slightly larger than the other denticles. No denticles were observed on the lateral process and it may therefore represent a juvenile Pa element (Fig. 11e) (Miller and Aldridge 1993).

Genus *Dapsilodus* Cooper, 1976

Type species

Distacodus obliquicostatus Branson and Mehl, 1933.

Dapsilodus obliquicostatus (Branson and Mehl, 1933)
Fig. 10j-l

Synonymy

See Armstrong (1990:70), plus the following:

1990 *Dapsilodus obliquicostatus* (Branson and Mehl) Uyeno, p. 98; pl. 2, figs 11-16.

?1992 *Dapsilodus* sp. Barrick and Klapper, p. 44; pl. 2, fig. 2.

1994 *Dapsilodus obliquicostatus* (Branson and Mehl); Sarmiento et al.; pl. 1, figs 1, 6.

1999 *Dapsilodus obliquicostatus* (Branson and Mehl); Cockle, p. 119; pl. 4, figs 13-19.

Description

See Cooper (1976:212).

Figured material

AM F128292 (Fig. 10j): M element; AM F128293 (Fig. 10k): M element, sample MU 38; AM F128294 (Fig. 10l): M element. All from sample MU 37 unless otherwise mentioned (Table 2).

Discussion

It has not been possible to separate the Sb and Sc elements from Murruin Creek as morphologies appear gradational and they have therefore been tabulated together (Table 2). The M elements recovered (Fig. 4j-l) are recurved with a prominent costa almost centrally positioned in lateral view. Oblique striations are present along the anterior margin in some elements. Among the M elements, the point of maximum curvature shows some variability in relation to the generally shallow basal cavity.

Genus *Decoriconus* Cooper, 1975

Type species

Paltodus costulatus Rexroad, 1967.

Decoriconus fragilis (Branson and Mehl, 1933)
Fig. 10m

Synonymy

See McCracken (1991:79), Zhang and Barnes (2002:11) and Farrell (2004:958).

Description

See Barrick (1977:53).

Figured material

AM F128295 (Fig. 10m): Sc element, sample MU 34 (Table 2).

Discussion

The Sc elements of *D. fragilis* from Murruin Creek are of the typical 'drepanodonti-form' first identified by Cooper (1975). These distinctive elements are inclined, with an almost straight anterior margin and are generally compressed, but expanded around the small basal cavity (Fig. 10m).

Genus *Kockelella* Walliser, 1957

Type species

Kockelella variabilis Walliser, 1957.

Kockelella maenniki Serpagli and Corradini, 1998
Fig. 11n, o

Synonymy

See Serpagli and Corridini (1999:284).

Description

See Serpagli and Corradini (1999:286).

Figured material

AM F128312 (Fig. 11n): Sc element; AM F128313 (Fig. 11o): Pa element. Both from sample MU 34 (Table 2).

Discussion

The laterally compressed Pa element of this taxon from Murruin Creek is curved, slightly arched and narrow with a strongly asymmetrical platform. The anterior portion of the blade has ten closely packed, compressed denticles. The posterior portion of the blade arches downwards and bears six closely spaced, laterally compressed denticles. The outer lateral process has five aligned, but slightly proclined denticles. The shorter inner lateral process appears to bear a single small denticle fused to the cusp (Fig. 11n). It should be noted that not all of Serpagli and Corradini's (1999:pl. 3, fig. 10) specimens have denticulate lateral processes. The Sc element is slender and has well-spaced denticles with a slightly twisted and downwardly deflected, antero-lateral process (Fig. 11n).

The stratigraphic range of *K. maenniki* is interpreted as restricted to the lower to middle part of the *P. siluricus* Zone (Corradini and Serpagli 1999; Serpagli and Corradini 1999). Corradini et al. (1998) reported that the genus *Kockelella* became extinct before the close of the *siluricus* Zone and that *K. maenniki* therefore represents the terminal taxon of the genus. *Kockelella maenniki* also occurs in the Ludlow Coral Gardens sequence of the Jack Formation in northern Queensland, where it occurs just below the youngest occurrence of *P. siluricus*.

Genus *Oulodus* Branson and Mehl, 1933

Type Species

Oulodus serratus Stauffer, 1930.

Oulodus sp. cf. *Oulodus elegans* (Walliser, 1964)
Fig. 11g, h

Figured material

AM F128305 (Fig. 11g): Sb element; AM F128306 (Fig. 11h): Sa element. Both from sample MU 34 (Table 2).

Discussion

The ramiform elements possess discrete, peg-like denticles and a prominent cusp that curves toward the lateral view. The anterior process of the Sb elements bear six or seven denticles and the postero-lateral process six denticles (Fig. 11g). The Sa elements are bilaterally symmetrical about the lateral processes which possess four denticles (Fig. 11h).

Genus *Ozarkodina* Branson and Mehl, 1933

Type species

Ozarkodina typica Branson and Mehl, 1933.

Ozarkodina excavata excavata (Branson and Mehl, 1933)
Fig. 11i-m

Synonymy

Simpson and Talent (1995:147) and Farrell (2003:123) covered the majority of published accounts. However, at least an additional 20 illustrated records pre- and postdating the synonymies cited above exist, but due to space limitations it was not possible to include them. This will be undertaken in another publication where the primary focus is conodont taxonomy.

Description

See Simpson and Talent (1995:152).

Figured material

AM F128307 (Fig. 11i): M element, sample MU 38; AM F128308 (Fig. 11j): Sa element; AM F128309 (Fig. 11k): Sb element; AM F128311 (Fig. 11l): Sc element; AM F128310 (Fig. 11m): Pa element. All from sample MU 34 unless otherwise mentioned (Table 2).

Discussion

This species from Murruin Creek shows the long, discrete denticles and well-developed basal cavity typical of this ubiquitous Silurian to Early Devonian taxon (Fig. 11i-m). The Sa elements show some variation in the angle between the processes (Fig. 11i), but Farrell (2003, 2004) reported similar variations in his material from the Late Silurian to Early Devonian Camelford Limestone and the Early Devonian Garra Limestone at Wellington in central-western New South Wales. The Pa and Pb elements display the typical anterior and posterior process morphology with closely packed compressed denticles and a prominent cusp (Fig. 11m, o).

Genus *Panderodus* Ethington, 1959

Type Species

Paltodus unicostatus Branson and Mehl, 1933.

Panderodus recurvatus (Rhodes, 1953)
Fig. 10n, o

Synonymy

See Simpson and Talent (1995:117) and Farrell (2003:122), plus the following:
1995 *Panderodus recurvatus* (Rhodes); Colquhoun, p. 354; pl. 3, fig. 4.
1999 *Panderodus recurvatus* (Rhodes); Cockle, p. 120; pl. 5, figs 9-14.
2002 *Panderodus recurvatus* (Rhodes); Aldridge; pl. 4, figs 4-7.
2002 *Panderodus recurvatus* (Rhodes); Talent et al.; pl. 2, figs J, K.
2002 *Panderodus recurvatus* (Rhodes); Zhang and Barnes, p. 31; figs 16.1-16.27.
2004 *Panderodus recurvatus* (Rhodes); Farrell, p. 958; pl. 3, figs 9, 12, 13.

Description

See Barrick (1977:54).

Figured material

AM F128296 (Fig. 10n): Sc element; AM F128297 (Fig. 10o): Sb element. Both from sample MU 34 (Table 2).

Discussion

The available elements of *P. recurvatus* from Murruin Creek are all broken to a greater or lesser extent, but are distinctly recurved, lack ornament and possess a longitudinal groove developed along the middle to posterior portion of one lateral surface (Fig. 10n, o).

Panderodus serratus Rexroad, 1967
Fig. 11c, d

Synonymy

1997 *Panderodus serratus* Rexroad; Jeppsson, p. 107; fig. 7.4.

Description

See Jeppsson (1997:107).

Figured material

AM F128299 (Fig. 11c): Sc element; AM F128298 (Fig. 11d): Sb element. Both from sample MU 34 (Table 2).

Discussion

Jeppsson (1997:107) noted a close similarity between *P. serratus* and *P. unicostatus*, and indicated they could only be separated by the serrate posterior margin of the arcuatiform (Sc) element of *P. serratus*. He did not, however, indicate whether serrations were present on other elements. The Murruin Creek specimens are rare (Table 2), but there are clear examples of a serrate Sc element (Fig. 11c) and one interpreted as a Sb element (Fig. 11d).

Panderodus unicostatus (Branson and Mehl, 1933)
Figs 10p; 11a, b

Synonymy

See Simpson and Talent (1995:118) and Farrell (2004:959), plus the following:
1997 *Panderodus unicostatus* (Branson and Mehl); Jeppsson, p. 107; fig. 7, 7.3.
1999 *Panderodus unicostatus* (Branson and Mehl); Cockle, p. 120; pl. 5, figs 1-8.
2002 *Panderodus unicostatus* (Branson and Mehl); Aldridge; pl. 4, figs 8-17.
2002 *Panderodus unicostatus* (Branson and Mehl); Talent et al.; pl. 2, fig. I.
2002 *Panderodus unicostatus* (Branson and Mehl); Zhang and Barnes, p. 32; figs 15.1-15.24.

Description

See Cooper (1976:213).

Figured material

AM F128302 (Fig. 10p): M element; AM F128300 (Fig. 11a): Sa element; AM F128301 (Fig. 11b): M element. All from sample MU 34 (Table 2).

Discussion

Despite being a ubiquitous component of many Silurian conodont faunas, the taxonomy of *P. unicostatus* is poorly understood. Specimens typically vary morphologically in terms of shape, total height and in the degree and location of strongest curvature (Jeppsson 1975; Simpson and Talent 1995). This variation between elements is such that distinction between S series elements is often problematic and intergradational morphologies possibly exist (Dzik and Drygant 1986; Sweet 1988). Jeppsson (1997) considered that internal structures of *Panderodus*, such as the form of the basal cavity and white matter distribution, to be taxonomically significant. Although over a thousand elements of this taxon were recovered from Murruin Creek (Table 1), many are broken at, or near the basal cavity termination.

ACKNOWLEDGEMENTS

The authors greatfully acknowledge the assistance provided in the field by John Talent, Ruth Mawson and Warrick Try. Peter Molloy assisted with acid processing of samples and shared his knowledge of Silurian conodonts. Heidi-Jane Caldon helped pick samples. John Paterson kindly identified trilobite remains recovered during this study. Peter Cockle and John Farrell generously donated specimens of *Acrotretella* from their conodont residues and Patrick Conaghan provided access to the linguliformean brachiopod fauna of the late Gunther Bischoff from the Boree Creek Formation. Dean Oliver skillfully drafted the geological maps and stratigraphic columns. This project would not have been possible without the generosity of Leo and Robin Chalker who kindly granted permission to collect samples on their property on several occasions. This manuscript benefited greatly from the constructive comments made by Glenn Brock (Macquarie University, Sydney) and two anonymous reviewers.

REFERENCES

Aldridge, R.J. (2002). Conodonts from the Skomer volcanic group (Llandovery Series, Silurian) of Pembrokeshire, Wales. *Special Papers in Palaeontology* **67**, 15-28.

Armstrong, H.A. (1990). Conodonts from the Upper Ordovician-Lower Silurian carbonate platform of North Greenland. *Grønlands Geologiske Undersøgelse Bulletin* **159**, 1-151.

Barrande, J. (1879). 'Système Silurien du centre de la Bohême. Iére partie. Recherches paléontologiques, vol. 5. Classe des Mollusques. Ordre des Brachiopodes.' (Published by the author: Prague and Paris).

Barrick, J.E. (1977). Multielement simple-cone conodonts from the Clarita Formation (Silurian) Arbuckle Mountains, Oklahoma. *Geologica et Palaeontologica* **11**, 47-68.

Barrick, J.E. and Klapper, G. (1992). Late Silurian-Early Devonian conodonts from the Hunton Group (Upper Henryhouse, Haragan, and Bois d'Arc Formations), south-central Oklahoma. *Oklahoma Geological Survey Bulletin* **145**, 19-65.

Bassett, M.G. (1986). Brachiopodes inarticules. *Biostratigraphie du Paleozoique* **3**, 85-96.

Bednarczyk, W. and Biernat, G. (1978). Inarticulate brachiopods from the Lower Ordovician of the Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica* **23**, 293-316.

Biernat, G. (1973). Ordovician inarticulate brachiopods from Poland and Estonia. *Palaeontologica Polonica* **28**, 1-120.

Biernat, G. (1984). Silurian inarticulate brachiopods from Poland. *Acta Palaeontologica Polonica* **29**, 99-103.

Biernat, G. and Harper, D.A.T. (1999). A lingulate brachiopod *Acrotretella*: new data from Ordovician of Poland. *Acta Palaeontologica Polonica* **44**, 83-92.

Bischoff, G.C.O. (1986). Early and Middle Silurian conodonts from midwestern New South Wales. *Courier Forschungsinstitut Senckenberg* **89**, 1-337.

Branson, E.B. and Mehl, M.G. (1933). Conodonts studies no. 1: conodonts from the Harding Sandstone of Colorado; Bainbridge (Silurian) of Missouri; Jefferson City (Lower Ordovician) of Missouri. *The University of Missouri Studies* **8**, 39-53.

Chatterton, B.D.E. and Whitehead, H.L. (1987). Predatory borings in the inarticulate brachiopod *Artiotreta* from the Silurian of Oklahoma. *Lethaia* **20**, 67-74.

Cherns, L. (1979). The environmental significance of *Lingula* in the Ludlow series of the Welsh Borderland and Wales. *Lethaia* **12**, 35-46.

Cockle, P. (1999). Conodont data in relation to time, space and environmental relationships in the Silurian (late Llandovery-Ludlow) succession at Boree Creek (New South Wales, Australia). *Abhandlungen de Geologischen Bundesanstalt* **54**, 107-133.

Cocks, L.R.M. (1979). New acrotretacean brachiopods from the Palaeozoic of Britain and Austria. *Palaeontology* **22**, 93-100.

Colquhoun, G.P. (1995). Early Devonian conodont faunas from the Capertee High, NE Lachlan Fold Belt, southeastern Australia. *Courier Forschungsinstitut Senckenberg* **182**, 347-370.

Cooper, B.J. (1974). New forms of *Belodella* (Conodonta) from the Silurian of Australia. *Journal of Paleontology* **48**, 1120-1125.

Cooper, B.J. (1975). Multielement conodonts from the Brassfield Limestone (Silurian) of southern Illinois. *Journal of Paleontology* **49**, 984-1008.

Cooper, B.J. (1976). Multielement conodonts from the St. Clair Limestone (Silurian) of southern Ohio. *Journal of Paleontology* **50**, 205-217.

Cooper, G.A. (1956). Chazyan and related brachiopods. *Smithsonian Miscellaneous Collections* **127**, 1-1024, 1025-1245.

Corradini, C. and Serpagli, E. (1999). A Silurian conodont biozonation from late Llandovery to end Přídolí in Sardinia (Italy). *Bollettino della Societá Paleontologica Italiana* **37**, 275-298.

Corradini, C., Ferretti, A., Serpagli, E. and Barca, S. (1998). The Ludlow-Pridoli Section "Genna Ciuerciu" west of Silius. *Giornale di Geologia* **60**, 112-118.

Davidson, T. (1848). Mémoire sur les Brachiopodes du Système Silurien supérieur de l'Angleterre. *Société Géologique de France, Bulletin* **5**, 309-338, 370-374.

Dean-Jones, G. (1979). Late Cambrian to Early Devonian inarticulate brachiopods from Australia: their classification, ontogeny, functional morphology and ultrastructure. Unpublished MSc thesis, Macquarie University, Sydney.

d'Orbigny, A. 1847. Considérations zoologiques et géologiques sur les Brachiopodes ou Palliobranches. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences* **25**, 193-195, 266-269.

Dzik, J. and Drygant, D.M. (1986). The apparatus of panderodontid conodonts. *Lethaia* **19**, 133-141.

Ethington, R.L. (1959). Conodonts from the Ordovician Galena Formation. *Journal of Paleontology* **33**, 257-292.

Farrell, J.R. (2003). Late Přidoli, Lochkovian and early Pragian conodonts from the Gap area between Larras Lee and Eurimbla, central western NSW, Australia. *Courier Forschungsintitut Senckenberg* **245**, 107-181.

Farrell, J.R. (2004). Siluro-Devonian conodonts from the Camelford Limestone, Wellington, New South Wales, Australia. *Palaeontology* **47**, 937-982.

Foerste, A. (1888). Notes on Paleozoic fossils. *Bulletin of the Scientific Laboratories of Denison University* **3**, 117-137.

Gorjansky, V.I. (1969). Bezzamkovye brakhiopody kembriiskikh i ordovikskikh otlozhenii sever-zapada Russkoi platformy. *Materialy po geologii i poleznym iskopaemym severo-zapada R.S.F.S.R.* **6**, 1-173.

Hall, J. (1872). Notes on some new or imperfectly known forms among the Brachiopoda, etc. *New York State Cabinet of Natural History, Annual Report* **23**, 244-247.

Haug, E. (1883). Ueber sogennannte *Chaetetes* aus mesozoischen Ablagerungen. *Neues Jahrbuch fuer Mineralogie, Geologie und Paläeontologie* **1**, 171-179.

Holmer, L.E. (1986). Inarticulate brachiopods around the Middle-Upper Ordovician boundary in Västergötland. *Geologiska Föreningens i Stockholm Förhandlingar* **108**, 97-126.

Holmer, L.E. (1989). Middle Ordovician phosphatic inarticulate brachiopods from Västergötland and Dalarna, Sweden. *Fossils and Strata* **26**, 1-172.

Holmer, L.E. (1991). The systematic position of *Pseudolingula* Mickwitz and related lingulacean brachiopods. In 'Brachiopods through time' (Eds D.I. MacKinnon, D.E. Lee and K.S.W. Campbell) pp. 15-21. (A.A. Balkema: Rotterdam).

Holmer, L.E. and Popov, L.E. (2000). Lingulata. In 'Treatise on Invertebrate Paleontology, part H, Brachiopoda (revised), vol. 2' (Ed. R.L. Kaesler) pp. 35-146. (Geological Society of America and The University of Kansas: Boulder and Lawrence).

Huleatt, M.B. (1969). The geology of Palaeozoic sediments south-east of Taralga, N.S.W. Unpublished BSc Thesis, Australian National University, Canberra.

Ireland, H.A. (1961). New phosphatic brachiopods from the Silurian of Oklahoma. *Journal of Paleontology* **35**, 1137-1142.

Jeppsson, L. (1975). Aspects of Late Silurian conodonts. *Fossils and Strata* **6**, 1-54.

Jeppsson, L. (1989). Latest Silurian conodont fauna from Klonk, Czechoslovakia. *Geologica et Palaeontologica* **23**, 21-37.

Jeppsson, L. (1997). A new latest Telychian, Sheinwoodian and Early Homerian (Early Silurian) standard conodont zonation. *Transactions of the Royal Society of Edinburgh: Earth Sciences* **88**, 91-114.

Jongsma, D. (1968). Geology of the upper Murruin Creek: an area between Mnt. Werong and Mnt. Shivering, N.S.W. Unpublished BSc Hons Thesis, University of New South Wales, Sydney.

Klyza, J.S. (1997). The Tamworth Belt in the Tamworth-Attunga area: stratigraphy, structure, biochronologic and palaeoenvironmental analysis. Unpublished MSc thesis, Macquarie University, Sydney.

Kutorga, S.S. (1846). Über das silurische und devonische Schichten-System von Gratschina. *Russisch-Kaiserliche Mineralogische Gesellschaft zu St. Petersbourg, Verhandlungen* **1845-1846**, 85-139.

Kutorga, S.S. (1848). Über die brachiopoden-familie der Siphonotretaeae. *Russisch-Kaiserliche Mineralogische Gesellschaft zu St. Petersbourg, Verhandlungen* **1847**, 250-286.

Link, A.G. and Druce, E.C. (1972). Ludlovian and Gedinnian conodont stratigraphy of the Yass basin, New South Wales. *Australian Bureau of Mineral Resources, Geology and Geophysics Bulletin* **134**, 1-136.

Ludvigsen, R. (1974). A new Devonian acrotretid (Brachiopoda, Inarticulata) with unique protegular ultrastructure. *Neues Jahrbuch fur Geologie und Paläontologie Monatschefte* **1974**, 133-148.

Matthews, K.M.C. (1985). The nature of the contact between the Burra Burra Creek Formation and the Cobra Formation, N.E. of Taralga, N.S.W. Unpublished BSc Hons Thesis, Macquarie University, Sydney.

Mawson, R., Talent, J.A. and Furey-Greig, T.M. (1995). Coincident conodont faunas (late Emsian) from the Yarrol and Tamworth belts of northern New South Wales and central Queensland. *Courier Forschungsinstitut Senckenberg* **182**, 421-445.

McCracken, A.D. (1991). Taxonomy and biostratigraphy of Llandovery (Silurian) conodonts in the Canadian Cordillera, northern Yukon Territory. *Geological Survey of Canada Bulletin* **417**, 65-95.

Mergl, M. (1982). *Caenotreta* (Inarticulata, Brachiopoda) in the Upper Silurian of Bohemia. *Věstník Ustředního ústavu geologického* **57**, 115-116.

Mergl, M. (1995). New lingulate brachiopods from the Milina Formation and the base of the Klabava Formation (late Tremadoc-early Arenig), central Bohemia. *Věstník Českého geologického ústavu* **70**, 101-109.

Mergl, M. (1996). Discinid brachiopods from the Kopanina Formation (Silurian) of Amerika quarries near Mořina, Barrandian, central Bohemia. *Časopis Národního Muzea Řada Přírodovědná* **165**, 121-126.

Mergl, M. (1999a). Genus *Paterula* (Brachiopoda) in Ordovician-Silurian sequence of central Bohemia. *Věstník Českého geologického ústavu* **74**, 347-362.

Mergl, M. (1999b). Genus *Lingulops* (Lingulata, Brachiopoda) in Silurian of the Barrandian. *Journal of the Czech Geological Society* **44**, 155-158.

Mergl, M. (2001). Lingulate brachiopods of the Silurian and Devonian of the Barrandian (Bohemia, Czech Republic). *Acta Musei Nationalis Prague, Series B, Historia Naturalis* **57**, 1-49.

Mergl, M. (2002). Linguliformean and craniiformean brachiopods of the Ordovician (Třenice to Dobrotivá Formations) of the Barrandian, Bohemia. *Acta Musei Nationalis Prague, Series B, Natural History* **58**, 1-82.

Miller, C.G. and Aldridge, R.J. (1993). The taxonomy and apparatus structure of the Silurian distomodontid conodont *Coryssognathus* Link and Druce, 1972. *Journal of Micropalaeontology* **12**, 241-255.

Morritt, R.F.C. (1979). Structural analysis of Palaeozoic rocks near Taralga, N.S.W. Unpublished BSc Hons Thesis, Macquarie University, Sydney.

Munson, T.J., Pickett, J.W. and Strusz, D.L. (2000). Biostratigraphic review of the Silurian tabulate corals and chaetetids of Australia. *Historical Biology* **15**, 41-60.

Naylor, G.F.K. (1937). Preliminary note on the occurrence of Palaeozoic strata near Taralga, N.S.W. *Journal and Proceedings of the Royal Society of New South Wales* **71**, 45-53.

Nazarov, B.B. and Popov, L.E. (1976). Radiolyarii, bezzamkovye brakhiopody i organizmy neyasnogo sistematicheskogo polozheniya iz srednego ordovika vosttochnogo Kazakhstana. *Paleontologicheskii Zhurnal* **4**, 33-42.

Nazarov, B.B. and Popov, L.E. (1980). Stratigrafiya i fauna kremnisto-karbonatnykh tolshch ordovika Kazakhstana (radioliarii i bezzamkovye brakhiopody). *Geologicheskiy Institut Akademii Nauk SSSR, Trudy* **33**, 1-190.

Philip, G.M. (1966). Lower Devonian conodonts from the Buchan Group, eastern Victoria. *Micropaleontology* **12**, 441-460.

Pickett, J.W. (Ed.) (1982). The Silurian System in New South Wales. *Bulletin of the Geological Survey of New South Wales* **29**, 1-264.

Pickett, J.W. (1985). Silurian corals from north of Wombeyan Caves. Unpublished Geological Survey of New South Wales Palaeontological Report **85/7**.

Pickett, J.W., Burrow, C.J., Holloway, D.J., Munson, T.J., Percival, I.G., Rickards, R.B., Sherwin, L., Simpson, A.J., Strusz, D.L., Turner, S. and Wright, A.J. (2000). Silurian palaeobiogeography of Australia. *Memoirs of the Association of Australasian Palaeontologists* **23**, 127-165.

Popov, L.E. (1981). Pervaia nakhodka mikroskopicheskikh bezzamkovye brakhiopod semeistva Acrotretidae v silurie Estonii. *Eesti NSV Teaduste Akadeemia Toimetised (Geologia)* **30**, 34-41.

Popov, L.E. (2000). Late Ordovician linguliformean microbrachiopods from north-central Kazakhstan. *Alcheringa* **24**, 257-275.

Popov, L.E. and Holmer, L.E. (1994). Cambrian-Ordovician lingulate brachiopods from Scandinavia, Kazakhstan, and South Ural Mountains. *Fossils and Strata* **35**, 1-156.

Powell, C.McA., Edgecombe, D.R., Henry, N.M. and Jones, J.G. (1976). Timing of regional deformation of the Hill End Trough: a reassessment. *Journal of the Geological Society of Australia* **23**, 407-421.

Powell, C.McA. and Fergusson, C.L. (1979a). Analysis of the angular discordance across the Lambian Unconformity in the Kowmung River – Murruin Creek area, eastern N.S.W. *Journal and Proceedings of the Royal Society of New South Wales* **112**, 37-42.

Powell, C.McA. and Fergusson, C.L. (1979b). The relationship of structures across the Lambian unconformity near Taralga, New South Wales. *Journal of the Geological Society of Australia* **26**, 209-219.

Rexroad, C.B. (1967). Stratigraphy and conodont paleontology of the Brassfield (Silurian) in the Cincinnati Arch area. *Indiana Geological Survey Bulletin* **36**, 1-69.

Rhodes, F.H.T. (1953). Some British Lower Palaeozoic conodont faunas. *Philosophical Transactions of the Royal Society of London B* **237**, 261-334.

Roots, W.D. (1969). The geology of the area around Bindook, New South Wales. Unpublished BSc Hons Thesis, University of New South Wales, Sydney.

Sarmiento, G., Mendez-Bedia, I., Arbizu, M. and Truyols, J. (1994). Early Silurian conodonts from the Cantabrian Zone, NW Spain. *Geobios* **27**, 507-522.

Satterfield, I.R. and Thompson, T.L. (1969). Phosphatic inarticulate brachiopods from the Bainbridge Formation (Silurian) of Missouri and Illinois. *Journal of Paleontology* **43**, 1042-1048.

Scheibner, E. (1973). 'Geology of the Taralga 1:100,000 sheet 8829'. (Geological Survey of New South Wales: Sydney).

Serpagli, E. and Corradini, C. (1998). New taxa of *Kockelella* (Conodonta) from late Wenlock-Ludlow (Silurian) of Sardinia. *Giornale di Geologia* **60**, 79-83.

Serpagli, E. and Corradini, C. (1999). Taxonomy and evolution of *Kockelella* (Conodonta) from the Silurian of Sardinia (Italy). *Bollettino della Societá Paleontologica Italiana* **37**, 275-298.

Sherwin, L. (1969a). Report on fossils from the Bindook 1:36,680 sheet (Burragorang IV 1:50,000) submitted by D. Roots. Unpublished Geological Survey of New South Wales Palaeontological Report **69/15**.

Sherwin, L. (1969b). Fossils from the Little Wombeyan Creek Limestone, Bindook 1:31,680 sheet (Burragorang IV 1:50,000). Unpublished Geological Survey of New South Wales Palaeontological Report **69/17**.

Sherwin, L. (1970). Lower Palaeozoic fossils from the Burragorang, Taralga and Katoomba 1:100,000 sheets. Unpublished Geological Survey of New South Wales Palaeontological Report **70/24**.

Sherwin, L. (1979). Late Ordovician and Late Silurian fossils from the Taralga district. Unpublished Geological Survey of New South Wales Palaeontological Report **79/14**.

Simpson, A.J. (1995a). Silurian conodont biostratigraphy in Australia: a review and critique. *Courier Forschungsinstitut Senckenberg* **182**, 325-345.

Simpson, A.J. (1995b). Silurian conodont studies in eastern Australia. Unpublished PhD thesis, University of Queensland, Brisbane.

Simpson, A.J., Bell, K.N., Mawson, R. and Talent, J.A. (1993). Silurian (Ludlow) conodonts and foraminiferas from Cowombat, southeastern Australia. *Memoirs of the Association of Australasian Palaeontologists*, **15**, 141-159.

Simpson, A.J. and Talent, J.A. (1995). Silurian conodonts from the headwaters of the Indi (upper Murray) and Buchan rivers, southeastern Australia, and their implications. *Courier Forschungsinstitut Senckenberg* **182**, 79-217.

Sowerby, J. de C. (1839). Shells. In 'The Silurian System, part II. Organic remains' (Ed. R.I. Murchison) pp. 579-712. (John Murray: London)

Stauffer, C.R. (1930). Conodonts from the Decorah Shale. *Journal of Paleontology* **2**, 121-128.

Stauffer, C.R. (1940). Conodonts from the Devonian and associated clays of Minnesota. *Journal of Paleontology* **14**, 417-435.

Strusz, D.L. and Munson, T.J. (1997). Coral assemblages in the Silurian of eastern Australia: a rugosan perspective. *Boletín de la Real Sociedad Española de Historia Natural Seccíon Geológica* **92**, 311-323.

Sweet, W.C. (1988). 'The Conodonta, morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phylum'. (Clarendon Press: New York).

Talent, J.A., Berry, W.B.N., Packham, G., Bischoff, G.C.O. and Boucot, A.J. (1975). Correlation of the Silurian rocks of Australia, New Zealand, and New Guinea. *Geological Society of America Special Paper* **105**, 1-108.

Talent, J.A., Mawson, R., Simpson, A.J. and Brock, G.A. (2002). Palaeozoics of NE Queensland: Broken River Region: Ordovician-Carboniferous of the Townsville

hinterland: Broken River and Camel Creek regions, Burdekin and Clark River basins. IPC2002 Post-5 Field Excursion Guide Book. *Macquarie University Centre for Ecostratigraphy and Palaeobiology Special Publication* **1**, 1-82.
Temple, J.T. (1987). Early Llandovery brachiopods of Wales. *Monograph of the Palaeontographical Society* **139**, 1-137.
Uyeno, T.T. (1990). Biostratigraphy and conodont faunas of Upper Ordovician through Middle Devonian rocks, eastern Arctic Archipelago. *Geological Survey of Canada Bulletin* **401**, 1-211.
Valentine, J.L. and Brock, G.A. (2003). A new siphonotretid from the Silurian of central-western New South Wales, Australia. *Records of the Australian Museum* **55**, 231-244.
Valentine, J.L., Brock, G.A. and Molloy, P.D. (2003). Linguliformean brachiopod faunal turnover across the Ireviken Event (Silurian) at Boree Creek, central-western New South Wales, Australia. *Courier Forschungsinstitut Senckenberg* **242**, 301-327.
von Bitter, P.H. and Ludvigsen, R. (1979). Formation and function of protegular pitting in some North American acrotretid brachiopods. *Palaeontology* **22**, 705-720.
von Eichwald, E. (1829). 'Zoologia Specialis, quam expositis animalibus tum vivis, tum fossilibus potissimum Rossiae in universum, et Poloniae in specie, in usum lectionum publicarum in Universitate Caesarea Vilnensi habendarum'. (Josephi Zawadzki: Vilniae).
Walliser, O.H. (1957). Conodonten aus dem oberen Gotlandium Deutschlands und der Karnischen Alpen. *Notizblatt des hessischen Landesamtes fur Bodenforschung, Wiesbaden* **85**, 28-52.
Walliser, O.H. (1964). Conodonten des Silurs. *Abhandlungen des Hessische Landesamtes für Bodenforschung* **41**, 1-106.
Williams, A. (2003). Microscopic imprints on the juvenile shells of Palaeozoic linguliform brachiopods. *Palaeontology* **46**, 67-92.
Wright, A.D. (1963). The fauna of the Portrane Limestone 1. The inarticulate brachiopods. *Bulletin of the British Museum (Natural History), Geology* **8**, 221-254.
Wright, A.D. and McClean, A.E. (1991). Microbrachiopods and the end-Ordovician event. *Historical Biology* **5**, 123-129.
Zhang Shun-xin and Barnes, C.R. (2002). A new Llandovery (Early Silurian) conodont biozonation and conodonts from the Becscie, Merrimack, and Gun River formations, Anticosti Island, Quebec. *Journal of Paleontology, Supplement* **76**, 1-46.